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GEOLOGICAL INVESTIGATIONS
OF
CHROMITE IN CALIFORNIA

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CHAPTER 4
CHROMITE DEPOSITS
OF EL DORADO COUNTY, CALIFORNIA

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CHROMITE DEPOSITS OF EL DORADO COUNTY, CALIFORNIA*

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U. S. Department of the Interior, Geological Survey

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ABSTRACT

El Dorado County, the largest source of chromite among the counties of the Sierra Nevada and the third largest source in California, lies along the west slope of the north-central Sierra Nevada. The chromite deposits, which are of two types—pod deposits and, of greater importance, disseminated deposits—occur in ultramafic rocks or in serpentine derived from them. The ultramafic rocks with some associated gabbro were intruded into pre-Tertiary sedimentary and volcanic rocks during a period of regional deformation. Somewhat later all these rocks were invaded by masses of diorite and granodiorite.

Known shipments of chromite from 1916 through 1945 amount to 44,036 long tons about equally divided between lump ore and concentrates. Estimated reserves in the county total more than 600,000 tons of material containing 5 percent or more of chromic oxide.

Descriptions of individual mines and prospects are based on published and unpublished information gathered chiefly during the years 1916-18 and 1939-45. A complete list of chromite mines and prospects with the production of each is included.

INTRODUCTION

El Dorado County, the largest source of chromite among the counties of the Sierra Nevada and the third largest source in California, has yielded 44,036 long tons[1] of chromite—about equally divided between lump ore and concentrates—since 1916 and an unknown amount previously. The only successful chromite concentrating plant operated in the United States during the period between World War I and World War II was at the Pillikin mine in El Dorado County. Unlike most counties in the Sierra Nevada, El Dorado County still contains sizeable reserves of chromite.

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[1] Considerable confusion has resulted from unspecified usage of the terms "ton", "short ton", and "long ton". Lump ore and concentrates are weighed and marketed in long tons, but in mining practice unmilled disseminated ore is measured in short tons. For the purposes of this report a "ton" is a short ton unless stated otherwise.

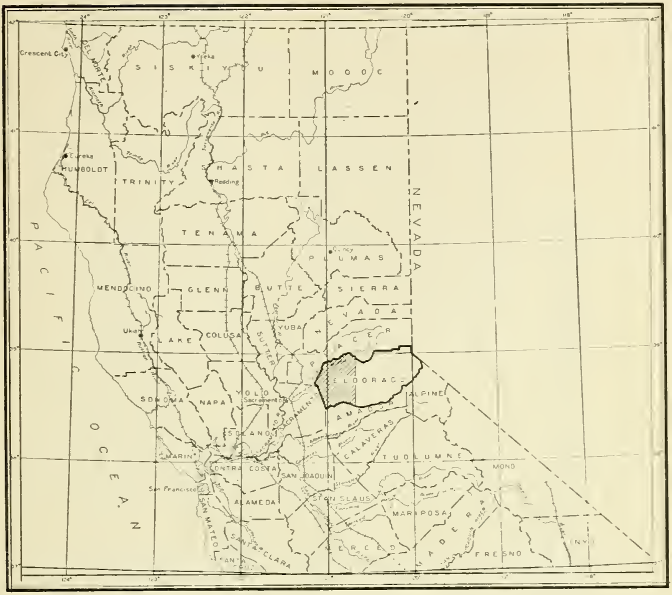


FIGURE 1. Index map of central California showing the location of El Dorado County and area (patterned) covered by plate 8.

Location, Topography, and Accessibility. El Dorado County comprises an area of 1,737 square miles on the west slope of the north-central Sierra Nevada between the Middle Fork of the American River and the South Fork of the Cosumnes River (see fig. 1). Elevations of about 200 feet along the rivers at the western border increase eastward to elevations of more than 10,000 feet along the crest of the Sierra Nevada. The western part of the county where the chromite deposits occur is rolling and hilly, except where cut by the deep canyons of the major streams, but the eastern part is rough and mountainous. The population is concentrated largely in the western half of the county, and this part is served by a network of roads, whereas much of the eastern part is inaccessible. A spur line of the Southern Pacific Railroad Co. extends eastward to Placerville and two local railroads, the Diamond and Caldor and the Camino, Placerville, and Lake Tahoe, traverse the south-central part of the county.

History and Production. Chromite was known to occur in El Dorado County as early as 1853 (Hanks 84), and Lindgren (94) reported that a few small pockets of chromite had been mined in the vicinity of Flagstaff Hill prior to 1894, but not until 1916 was any appreciable quantity produced. The long delay in exploiting the deposits in this

Table 1. Shipments of chromite by mines from El Dorado County, California, 1916-1945 [1]

(In long tons)

Property	Map No.	1916	1917	1918	1919-1935		1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	Total
					Year	Tons											
Black Oak	45	-------	-------	36	-------	-------	-------	-------	-------	-------	-------	-------	91	16	-------	-------	143
Burnett	20	-------	-------	139	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	139
Chaix	11	-------	45	36	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	81
Chrome Divide	50	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	15	-------	36	-------	-------	51
Darrington	21	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	31	-------	454	-------	485
Dobbas	25	-------	-------	683	-------	-------	-------	-------	-------	-------	-------	-------	20	10	-------	-------	713
Forni	51	-------	-------	1	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	1
Gordon	30	-------	-------	31	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	31
Green mine	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	64	-------	-------	-------	64
Helemar	2	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	54	33	87
Hoff	1	-------	107	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	107
Irish	28	-------	-------	18	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	18
Joerger	16	-------	-------	[2]	-------	-------	-------	-------	-------	-------	-------	-------	[4]	-------	-------	-------	-------
Knoff mines	49	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	28	38	28	-------	94
Maxwell	37	446	241	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	687
McDonald and Buys	32	-------	-------	36	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	36
Mundrini	-------	-------	-------	16	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	16
Murphy	10	297	426	2,174	-------	-------	-------	-------	-------	-------	-------	-------	[4]	-------	-------	-------	2,897
O'Brien	36	-------	-------	[3]	-------	-------	-------	-------	-------	-------	-------	-------	[4]	-------	-------	-------	-------
Pfeiffer	7	-------	13	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	13
Pillikin:																	
Areas 1, 2, and 3 mostly	23	2,137	3,398	3,624	1931	10	30	464	759	3,036	1,772	4,418	7,061	273	-------	162	27,144
Areas 5, Placer Chrome Co.	26	357	2,362	4,048	1920	503	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	7,270
Area 9, Nielson and Donnelly	24	140	84	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	224

Shelly	39	-------	506	778	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	1,284
Sheppard	42	-------	-------	[3]	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Simon	38	-------	-------	49	1920	45	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	94
Simpson	19	-------	54	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	54
Stafford	48	-------	91	107	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	198
Steele	22	-------	-------	313	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	313
Volo Milling Co.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	534	12	-------	-------	546
Walker	17	-------	[2]	[2]	-------	-------	-------	-------	-------	-------	-------	-------	[4]	-------	-------	-------	-------
Wiley	33	45	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	45
Others	-------	76	-------	272	1920	8	-------	-------	-------	-------	-------	-------	53	-------	-------	-------	409
	-------	-------	-------	[5]356	1919	[5]425	-------	-------	-------	-------	-------	-------	-------	-------	[5]11	-------	792
Totals	-------	3,498	7,327	12,717	-------	991	30	464	759	3,036	1,772	4,433	7,882	385	547	195	44,036

---

[1] Compiled from Federal records only. Amounts of small shipments prior to 1916 are not known.
[2] Included under Murphy mine.
[3] Included under Shelly mine.
[4] Included under Volo Milling Company.
[5] Production apportioned to El Dorado Co. from shipments including ore from other counties.

county is rather surprising, for neighboring counties no more advantageously situated had yielded considerable quantities of chromite for many years prior to 1916. Wartime demand and increased prices finally stimulated exploration and development, and in 1916 a number of properties began shipping chromite; by 1918 more chromite was being produced in El Dorado County than in any other county in the state and five concentrating plants were operating. The collapse of the market following the end of the war greatly reduced production, and chromite mining ceased by 1921. All the mines remained inactive until the Pillikin mine was reopened in 1936. About half the old mines were reworked during the period 1936-45, but again low postwar prices for chromite has caused all the mines to cease operations.

Production data for El Dorado County probably are known more accurately than for most other counties in the state, although data on the World War I production of a number of mines are either incomplete or non-existent. At least 53 deposits, or groups of deposits, of chromite have been worked in El Dorado County, and up to December 31, 1945 had yielded a recorded total of 44,036 long tons of chromite (see table 1). The production listed in table 1 includes only those data from which the county totals in the annual volumes of the Mineral Resources of the United States were calculated. In the descriptions of individual properties, production estimates by others, chiefly Taliaferro (Louderback 18), are given for those properties for which Federal records are lacking or appear to be incomplete. Shipments of chromite since 1936 are accurately known and represent the actual output.

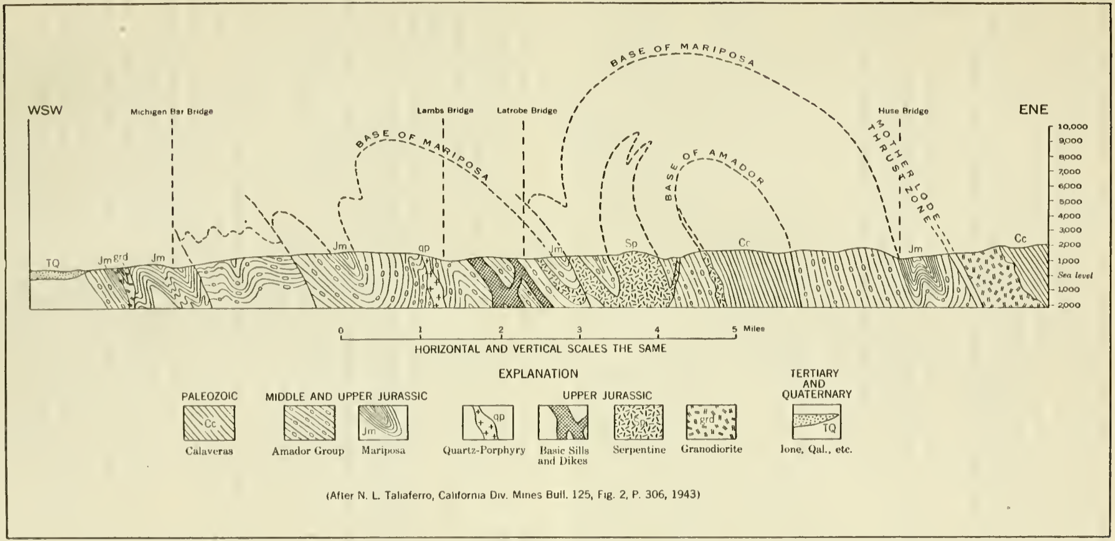
Scope of Report and Acknowledgments. This report is based partly on material collected and mapping done intermittently from 1942 to 1949 by the authors under the direction of Francis G. Wells, and partly on data contained in published and unpublished Federal and State reports, which are listed at the end of this report. Many of the properties in the county were examined by the authors, but no attempt was made to visit all the smaller mines. Some of the mines reported to have yielded considerable chromite during World War I could not be found. Studies on some of the chromite-producing areas were terminated before completion and as a result, some of the information is sketchy and incomplete. The report was prepared mainly by Fred W. Cater, Jr., with the assistance of G. A. Rynearson and D. H. Dow. Friendly and helpful criticism has been given by F. G. Wells and T. P. Thayer.

The writers are indebted to the personnel of the Rustless Mining Corporation and of U. S. Chrome Mines, Inc. for their unfailing cooperation. Mr. Charles J. Hendrickson of the Rustless Mining Corporation and Mr. George Beers of U. S. Chrome Mines, Inc. were especially helpful. Mr. J. J. Taylor furnished valuable information on some deposits in the county.

GEOLOGY

The rocks of El Dorado County may be considered conveniently in two categories: pre-Tertiary and Tertiary. The pre-Tertiary rocks are highly folded metamorphosed sedimentary and volcanic rocks cut by numerous masses of various igneous rocks. The Tertiary rocks are slightly tilted stream gravels and volcanic flows and tuffs.

The oldest rocks in the county are mica schists, meta-cherts, quartzites, argillites, crystalline limestones, and schistose metavolcanic rocks



(After N. L. Taliaferro, California Div. Mines Bull. 125, Fig. 2, P. 306, 1943)

GENERALIZED SECTION ALONG COSUMNES RIVER

FIGURE 2.

belonging to the Calaveras formation. Most of the rocks in this formation are believed to be of Carboniferous age, although rocks of Paleozoic age other than Carboniferous also may be present. Unconformably overlying the Calaveras formation are Middle and Upper Jurassic rocks comprising a series of sandstones, conglomerates, bedded tuffs, cherts, slates, and limestones, and thick layers of augite andesite and dacite. These rocks have been described by Taliaferro (43) and named the Amador group. Some of these rocks were mapped earlier on the Sierran folios of the U. S. Geological Survey as part of the Calaveras formation. The Upper Jurassic Mariposa slate overlies the Amador group either conformably or nearly so. Near the close of the Jurassic the rocks were intruded by masses of ultramafic rocks, gabbrodiorite, and granodiorite, in the order named, about the same time that the main Sierra Nevada batholith was emplaced.

The pre-Tertiary rocks have been compressed into a series of north-northwest trending, tight, nearly isoclinal folds that are overturned to the west so that the regional dips are easterly (see fig. 2). Further compression of the folded rocks produced zones of east-dipping, high-angle reverse faults parallel to the axial planes of the folds. The gold-quartz veins of the Mother Lode formed in one of these fault zones.

The slightly tilted Tertiary rocks, consisting of andesitic and rhyolitic flows and tuffs and scattered patches of early stream gravels, overlie the truncated folds of the older rocks. The volcanic rocks cover large areas from north to south across the middle of the county, but only small, isolated patches remain in the western part of the county.

Ultramafic Rocks

Lithologic Character. Primary concentrations of chromite occur only in ultramafic rocks, which are those intrusive rocks that are rich in magnesium and iron and deficient in alkalies and silica. Olivine and pyroxene are the essential minerals of this class of rocks; accessory chromite commonly is present. Pure olivine rock is called dunite and pure pyroxene rock is called pyroxenite, whereas intermediate types, containing both olivine and pyroxene, are called peridotites and are commonest. Olivine alters readily and pyroxene less readily to minerals of the serpentine group, and olivine-pyroxene rock so altered is called serpentine. Most of the ultramafic rocks in El Dorado County are serpentinized, but in this report rocks whose original composition is evident are referred to by their varietal names.

Two varieties of peridotite, saxonite and lherzolite, have been identified in El Dorado County. Saxonite, composed of olivine and orthorhombic pyroxene (enstatite), is most abundant; lherzolite, composed of olivine and both orthorhombic and monoclinic pyroxenes (enstatite and diallage), is predominant in the Flagstaff Hill ultramafic mass, but appears to be rare in other masses. Both fresh pyroxene and its serpentinized equivalent, bastite, weather less rapidly than fresh or serpentinized olivine, and, as a result, weathered saxonite and lherzolite have characteristic rough surfaces on which pyroxene and bastite crystals stand out. Weathered surfaces of saxonite and lherzolite are red, buff, or brown, but the unweathered rock commonly is glassy and light green if fresh and very dark green or black if serpentinized.

Dunite is a dense, even-grained rock in which no minerals except accessory chromite stand out. Serpentinized dunite fractures with smooth, conchoidal surfaces in distinct contrast to the rough, uneven surfaces of fractured saxonite and lherzolite. Weathered surfaces are smooth and have a buff or yellowish brown color.

Pyroxenite is the toughest and most resistant to weathering of the ultramafic rocks, and commonly forms bold, jagged outcrops. The rock is coarse-grained, has a greenish color, and a very rough and hackly fracture. It is far less susceptible to serpentinization than other ultramafic rocks.

Zones of highly sheared, soft, light green serpentine, which breaks down into translucent, slick scale-like particles, are common in most areas of serpentinized ultramafic rocks, especially along contacts. This material has been very aptly called ''slickentite''.

Structure and Distribution. Most of the ultramafic masses in El Dorado County are sill-like and trend north or north-northwest parallel to the strike of the enclosing metamorphic rocks. All the ultramafic masses are restricted to rocks of the Amador group and the Calaveras formation except one long, very narrow body extending northward from Placerville, which intrudes Mariposa slate. In several places ultramafic masses are localized along contacts between rocks of the Amador group and the Calaveras formation. Considerable gabbro is associated with the ultramafic rocks in some localities; the two rocks appear to be nearly contemporaneous, but both are older than granodiorite, diabase, and diorite. Large intrusions of granodiorite cut off some bodies of ultramafic rocks and gabbro, and dikes of diabase and diorite are common in some of the others.

The ultramafic sills probably were intruded while folding was still in progress as they in part have been involved in the same deformation as the host rocks. Some parallel outcrop areas of ultramafic rocks represent truncated limbs of a folded sill rather than separate masses; the bifurcated outcrop patterns probably indicate sills deformed into plunging folds.

The ultramafic rocks in El Dorado County lack to a considerable degree the regularity of distribution so marked in the neighboring counties to both the north and south, where most ultramafic masses are confined to distinct belts. In El Dorado County, although such belts exist, many of the masses are scattered haphazardly and manifest no obvious zonal arrangement. The western serpentine belt that trends north-northwestward across Tuolumne, Calaveras, and Amador Counties splits northward into divergent branches at the El Dorado County line; the western branch continues along the same north-northwesterly strike almost to the American River, but the eastern branch trends almost due north to a point about halfway across the county and then frays out into numerous, widely scattered masses. (See pl. 8.)

Ten areas of ultramafic rocks have been mapped in the western branch, but these do not necessarily represent ten independent masses, as some of the parallel areas may represent the exposed limbs of folded sills. The smaller areas are only a few hundred feet wide and half a mile long; the larger ones are half a mile to 1½ miles wide and 3 to 7 miles long. All the ultramafic masses of the western branch intrude rocks of the Jurassic Amador group and dip eastward parallel to the dip of the enclosing rocks.

The eastern branch comprises a number of northward trending masses. Some of these have extremely irregular outlines and probably represent highly crumpled tabular bodies. The irregular mass that extends northward through Shingle Springs is cut off one mile south of Lotus by a large north-northwest trending mass of granodiorite, but north of the granodiorite, 2 miles north of Lotus, another mass of ultramafic rocks crops out. These two masses may have been continuous before intrusion of the granodiorite. The ultramafic rocks of the eastern branch intrude rocks of both the Amador group and the Calaveras formation, in places along the contact between them.

Scattered over Townships 11 and 12 N., R. 9 E., from near the mouth of Webber Creek to Greenwood, are numerous rather small masses of ultramafic rocks. These trend north-northwesterward parallel to the strike of the enclosing rocks, and like the masses of the eastern branch they intrude both Jurassic and Carboniferous rocks or follow the contacts between them. Except for one mine in the mass southwest of Pilot Hill, very little chromite has been found in any of these bodies. Unlike other ultramafic masses in the county, the Pilot Hill mass is relatively unaltered.

The great eastern belt of ultramafic rocks is an apparently continuous mass about 70 miles long that extends from a point 3 miles northeast of Garden Valley northward across Placer, Nevada, and Sierra Counties into Plumas County. It consists largely of serpentinized ultramafic rocks but is, however, a complex mass and contains large amounts of gabbro and diorite. Where the belt cuts across rocks of both the Amador group and the Calaveras formation in El Dorado County, it is characteristically dikelike, but elsewhere parts of the belt intrude the older rocks conformably.

Occurrence of Dunite. Dunite is the only variety of ultramafic rock that contains large concentrations of chromite. The ratio of dunite to pyroxene-bearing peridotite in any ultramafic mass varies widely, and in El Dorado County the proportion of dunite is small. Individual dunite bodies may be of almost any size or shape and may occur anywhere in an ultramafic mass, but if large, the bodies tend to be lenticular and are elongated in the direction of the elongation of the enclosing mass. Disseminated deposits of chromite are more apt to occur in large bodies of dunite, whereas pods of massive chromite ore commonly occur in the smaller bodies of dunite; however, either type may occur in dunite bodies of all sizes. The size of a dunite mass is not indicative of the size of any ore bodies that it may contain. Some large dunite masses apparently contain no ore bodies, whereas some massive ore bodies have only a thin rind of dunite surrounding them.

CHROMITE DEPOSITS

Characteristics of Chromium Ores

Composition of Chromite. The only ore mineral of chromium is chromite, a black or brownish-black mineral with a brown streak and commonly but not invariably a submetallic luster; it is easily scratched with a knife. Sheared or finely crushed chromite has a characteristic chocolate color and a dull, earthy luster. Chromite is an isometric mineral of the spinel group, and like most spinels, is an isomorphous compound of several end members or minerals. The end members, magnesiochromite

($MgO \cdot Cr_2O_3$), ferrochromite ($FeO \cdot Cr_2O_3$), spinel ($MgO \cdot Al_2O_3$), hercynite ($FeO \cdot Al_2O_3$), magnesioferrite ($MgO \cdot Fe_2O_3$), and magnetite ($FeO \cdot Fe_2O_3$) combine in different proportions and form chromites having widely different compositions. (Stevens 44). Thus, chromites from different deposits may differ in composition, and, indeed, may differ within a single pod, although within a more limited range. Recent work by Thayer (46) indicates that a definite chemical correlation exists between the composition of chromite and the containing rocks.

As is common with chromite elsewhere in the Sierra Nevada, the chromite in El Dorado County ranges rather widely in composition and much of it is rather high in iron. Nevertheless, a large amount of the chromite shipped from the county has been of a fairly good grade. A number of complete and partial analyses of chromite from the Pillikin mine are given in tables 2 and 3 under the description of that mine.

Specifications. The value of chromite depends not on the chromium content alone but also on the content of other metallic elements. Metallurgical grades should contain at least 45 percent of chromic oxide and 3 parts of chromium for each part of iron. Chromites relatively low in chromic oxide are satisfactory for refractory purposes providing the content of aluminum oxide is sufficient to make the combined content of the two oxides at least 60 percent of the mineral. The chief requirement for chemical grade ore is that it shall contain sufficient chromium to make conversion to chromium salts worthwhile. Silica is undesirable and more than 10 percent renders an ore unsuitable for metallurgical uses. Ores containing more than 0.5 percent of sulphur or more than 0.2 percent of phosphorous are undesirable also, but these elements commonly are not present in such amounts.

Other Chromium Minerals. Several secondary chromium-bearing minerals are present in small amounts in many chromite deposits, but are never of economic significance. Uvarovite, the chrome garnet, and kammererite, a chrome chlorite, probably are the commonest. Uvarovite is emerald green, has a vitreous luster, and is harder than most other garnets. It forms drusy incrustations of small dodecahedral or trapezohedral crystals in joints and fractures in chromite, but more commonly is seen as green smears on slickensided surfaces of chromite. Kammererite is a reddish-purple micaceous mineral that likewise forms in fractures in chromite or in the adjacent gangue. It is easily mistaken for kotschubeite, another chromium-bearing chlorite of similar appearance.

Ore Bodies

As elsewhere in California, both disseminated and massive chromite deposits are found in El Dorado County. Classification of a deposit as one type or the other depends on the nature of the major part of the ore contained in the deposit. Ore consisting of separate chromite grains either evenly or unevenly dispersed in varying proportions of olivine or serpentine is called disseminated ore, and a deposit consisting wholly or mostly of this kind of ore is known as a disseminated deposit. Ore consisting of closely packed, almost pure aggregations of chromite grains usually is called massive ore, and a deposit of such ore is a massive deposit. The distinction between disseminated ore and massive ore rests mainly on the relative amount of chromite in any given unit of the ore.

and, although no sharp line can be drawn between the two kinds, ore containing more than 75 percent of chromite usually could be classed as massive ore. The two kinds of ore may occur together or separately. In general, disseminated ore requires some concentration to make it marketable, whereas massive ore usually can be sold in its crude state.

Deposits of Disseminated Ore. Deposits of disseminated ore may occur anywhere within a dunite mass. They may consist of chromite grains distributed more or less evenly through the host rock, but more commonly the chromite occurs as irregular lenses, streaks, or clots; as alternating layers of rich and lean accumulations; and as oriented pencil-like linear aggregations. In a few places nodular ore consisting of spheroid or ovoid globules has been found. Ore bodies of the disseminated type grade outward into dunite containing only accessory chromite.

Although disseminated ore bodies generally have a tabular or lenticular form, they may be highly irregular. The deposits and their internal elements or structures commonly lie parallel to the long dimension of the enclosing ultramafic mass or, if this mass is essentially equi-dimensional, to the nearest contact. In detail, however, the lenses and layers of ore may be intensely deformed and contorted.

The disseminated chromite deposits of El Dorado County vary greatly in size. Some deposits contain only a few hundred pounds of ore; others, like some at the Pillikin mine, contain many thousand tons of ore.

The practicability of concentrating disseminated ores depends on a number of factors such as the grade of the ore, the composition of the pure chromite, the size of the chromite grains, and the nature of the gangue. The lowest grade mill feed treated at the Pillikin mill during World War II contained 7 percent of Cr_2O_3, but the operators considered 5 percent of Cr_2O_3 as the cutoff grade. The grade of chromite concentrates depends directly on the composition of the mineral, and consequently a high-grade concentrate cannot be made from an ore containing chromite of unfavorable composition. The amount of grinding necessary to free the chromite from the gangue depends in large measure on the size of the chromite grains, and because chromite crushes readily, excessive sliming losses may result from the amount of grinding necessary for fine-grained ores. The fine grinding necessary to liberate the chromite from silicified ore may result in high sliming losses also.

Deposits of Massive Ore. Massive ore occurs as irregular stringers, lenses, and pod-shaped masses of pure or nearly pure chromite, and because of their shape many such masses often are called pod deposits. Like disseminated ore they may occur anywhere within either large or small dunite masses. The contacts between bodies of massive ore and the surrounding dunite generally are sharp and sheared, but if unsheared a thin transitional zone of disseminated ore may surround the massive ore.

Pods of massive chromite generally are found in zones of shearing. The borders of chromite pods are inherently zones of weakness along which shearing is most likely to occur, and not uncommonly a shear zone is localized around a pod and extends but relatively short distances beyond it. Differential and rotational stresses undoubtedly impart rotational movements to chromite pods, aiding materially in the creation of encompassing shear zones. Shearing accounts in part for some of the irregularities of form so common in chromite pods and tends to orient the pods with their long axes parallel to the plane of shearing. Consequently the direction of elongation of a pod or string of pods is the one along which to search for additional ore. Most ultramafic or serpentine masses have many shear zones, some of which are hundreds of feet wide and miles long, although most are much smaller, but not all shear zones, of course, contain chromite; only those that follow pre-existing ore bodies will be productive. Unless ore has been found in a shear zone, it is not yet possible to predict whether or not any given shear zone contains ore.

Size. Allen (38) classified chromite deposits as (1) small, containing less than 100 long tons; (2) medium, containing 100 to 1,000 long tons; and (3) large, containing more than 1,000 long tons. Of the 235 deposits he listed, 48 percent were classed as small, 24 percent as medium, and 28 percent as large. Many disseminated deposits were included in his list and the deposits included were probably above average size. Wells (46) concluded that of the pod deposits in Del Norte County, 72 percent are small, 20 percent are medium, and only 8 percent are large. Cater (48) concluded that 37 percent of the deposits mined in Tuolumne County were small, 56 percent were medium, and 7 percent were large. Of the 53 deposits of massive and disseminated ore that have been worked in El Dorado County, 50 percent are small, 34 percent are medium, and 16 percent are large. If pods of massive chromite alone are considered, only 7 percent are large and the medium and small deposits are about equally divided. Although the proportion of medium and small deposits may vary considerably, the proportion of large deposits seems to be constant, and in El Dorado County, as elsewhere in California, only about one deposit in ten is large.

Reserves. Because of the erratic distribution and highly irregular shapes of chromite ore bodies, mine operators have not considered it economical to block out much ore in advance of mining or to indicate large reserves in excess of their current needs. As a result, reserves that are blocked out sufficiently well to be calculated with a small error of tonnage and grade, and thus classed as ''measured reserves'', are small and are included here in the estimates of indicated reserves. Reserves that are estimated from surface exposures, underground workings, and projections for reasonable distances on geologic evidence are classified as ''indicated reserves.'' Undiscovered ore is classified as ''potential reserves'', but no estimates will be given for this class.

The accuracy of an estimate of indicated reserves of chromite is subject to a large margin of error because of the irregular shapes of the ore bodies and the necessity of relying on visual estimates of ore grade. Many bodies of disseminated ore grade outward into barren dunite by gradual decrease in chromite content, and a small error in estimating a cutoff grade may introduce a large error in tonnage calculations. Indicated reserves of chromite in El Dorado County, as estimated in early 1945, are larger than for any other county in the Sierra Nevada. Most of these reserves consist of disseminated ore and by far the largest amounts are in the Flagstaff Hill area. An indicated reserve of the order of perhaps 600,000 tons of material containing 5 percent or more Cr_2O_3 remains in the various deposits in this area, although much of it is in bodies too small to mine by cheap methods. Elsewhere in the county between 20,000 and 30,000 tons of similar material remains. Reserves of shipping-grade or massive ore in the county are very much smaller. Many of the deposits containing such ore have been mined out and reserves in others are small. Probably not more than a few thousand long tons of shipping-grade ore could be mined from deposits close to the surface, and most of this would come from high-grade lenses in the disseminated deposits.

Inasmuch as chromite is a magmatic segregation it is reasonable to suppose that there is no significant decrease in the number of ore bodies at depth—or for that matter, of any consistent change in the grade of the ore or composition of the chromite. Therefore, potential reserves at considerable depths may be very large. However, the cost of finding and mining any such ore bodies has been prohibitive under price conditions that have prevailed in the past, and no attempt will be made here to estimate potential reserves.

DESCRIPTION OF DEPOSITS

The chromite deposits of El Dorado County are described by areas; each area includes the deposits within a single ultramafic mass or group of adjacent masses that are confined to a relatively restricted locality. These areas have been designated as the Latrobe, Clarksville, Flagstaff Hill, Webber Creek, Pilot Hill, Garden Valley, and Georgetown-Volcanoville areas, and are considered in the order given. Except in the Flagstaff Hill area, the deposits in each area are described in the numerical order indicated by the numbering shown on plate 8. This system has been modified in the case of the Flagstaff Hill area so that the detailed description of the principal mine in the area, the Pillikin mine, could be given first.

Latrobe Area

Most of the chromite deposits of the Latrobe area lie 2 to 4 miles east and southeast of Latrobe, but two deposits lie northwest of the village. The part of the area drained by Big Canyon Creek is rather steep and rugged, but the rest of the area is rolling and less rough. The chromite deposits occur in two masses of ultramafic rocks that intrude the bedded tuffs, cherts, slates, and sandstones of the Cosumnes formation (of Taliaferro 43) of the Amador group. The two ultramafic masses may be connected at depth as they appear to be the exposed limbs of a synclinally folded sill.

Trio Chrome Company Leases (1-3)

The Trio Chrome Company leases are about 5 miles southeast of Latrobe and cover 315 acres owned by Robert Haddock and R. H. Chaix in secs. 24 and 25, T. 8 N., R. 9 E. and secs. 19 and 30, T. 8 N., R. 10 E. Included in the leases are the old Hoff property and Helemar claim, both in sec. 30, and some chromite-bearing placer ground in sec. 25. Only the Helemar claim and the placer ground have been worked since 1918.

Hoff Property (1). Workings on the Hoff property are in the W½ sec. 30 and consist of an open cut 60 feet long, 10 feet wide, and 20 feet deep at its deepest end. From this open cut was mined a lens of chromite striking N. 60° W., dipping 70° NE., and pitching 25° SE. The lens had a length of 60 feet, a maximum thickness in the center of 10 feet, and tapered toward both ends. The ore is coarse-grained and ranges from a medium-grade disseminated ore containing 40 percent of serpentine gangue to nearly pure chromite. The ore body is considerably brecciated and shattered, and the surrounding serpentine country rock is highly sheared. Contacts between the chromite and serpentine are slickensided.

According to Taliaferro (in Louderback 18) and Logan (in Bradley 18), about 200 long tons of ore containing 28 to 33 percent of Cr_2O_3 was shipped during World War I, but the production listed in Federal records amounts to only 107 long tons. About 20 long tons of ore remain on the dump, but unmined reserves are nearly exhausted.

Placer Ground (2). The placer ground is in the NE¼ sec. 25, 5 miles by dry-weather road from the paved Latrobe-Shingle Springs highway. Several acres of gravel and hill wash 1 to 10 feet deep cover the bottom and sides of a shallow gulley tributary to the Cosumnes River, which flows a short distance to the south. About 2 acres of these gravels have been uncovered with a bulldozer and several small exploratory trenches have been excavated. According to the operators, each ton of soil and gravel contains about 30 pounds of chromite sand, which is derived from the serpentine that crops out at the head and along the east side of the gulley. The west side of the gulley is underlain by metamorphic rocks of the Amador group. No chromite concentrates have been shipped, as far as is known, and the placer operations were designed originally to work the area for gold.

Helemar Claim (3). The old Helemar claim lies in the NW¼ sec. 30. It was not visited by members of the Geological Survey and nothing is known about the workings or the geology. In 1944-45 about 57 long tons of ore containing 38 percent of Cr_2O_3 was shipped to the Auburn stockpile of the Metals Reserve Co.

Gold Bug Claims (4)

The Gold Bug claims are 4 miles southeast of Latrobe in sec. 19, T. 8 N., R. 10 E., about 1 mile north of the Cosumnes River and near the crest on the east side of the ridge east of Big Canyon Creek. The claims were staked by R. H. Chaix and George Gardner in 1941 as the Gold Bug claims, and appear to be on the same deposits as those described by Taliaferro in 1918 as the Ehler and Hoff claims. The deposits have been explored by several trenches, a short inclined shaft, and areas scraped to bedrock by a bulldozer. Most of this work has been done on a narrow zone of low-grade disseminated and banded ore from 1 foot to 3 feet wide with an exposed length of 125 feet. The zone strikes N. 50° W. and dips 30° NE. The matrix of the ore and the country rock immediately surrounding the ore is serpentinized dunite, some of which contains peculiar rounded grains of an unidentified carbonate mineral measuring 1 millimeter or 2 millimeters across. Most of the ore is conspicuously banded, but irregular knots and clots of high-grade chromite are common. Individual chromite grains are rather small and average about one-half millimeter in diameter.

Scattered elsewhere over the claims are several other very small deposits from which minor amounts of massive chromite has been mined. The claims are reported by Taliaferro to have produced about 16 tons of chromite. Several tons of low-grade ore is piled on various dumps, and 100 to 200 tons of such ore remains in place.

Freeman Mine (5)

E. L. Freeman is alleged to have mined 40 long tons of ore in 1918 from a deposit in the SE¼ sec. 24, T. 8 N., R. 9 E. According to Logan (in Bradley 18), "A lens of chrome, in serpentine, striking north-south, and pitching 85° W. was mined by an open cut 2′-3′ deep and 30′ long." The mine was not visited by members of the Geological Survey.

Bryant Mine (6)

The Bryant mine is on the west bank of Big Canyon Creek in the SE¼ sec. 13, T. 8 N., R. 9 E. The deposit was worked briefly in 1918 when exposed by floodwaters from Big Canyon Creek. The production for that period is not known. Some years later dragline dredging operations on the creek uncovered the ore body and excavated blocks of chromite from the bedrock. These blocks, some weighing as much as 200 pounds, now lie on the crests of east-west tailing piles for a distance of 200 feet along a line that trends N. 20° E. The size and quantity of chromite blocks indicate the presence of a moderate-sized body of ore. The ore body lies parallel to and from 125 to 190 feet southwest of the line of chromite blocks, but is buried under 4 to 10 feet of gravel. The ore is coarse-grained, nearly pure chromite, and judging from the material on the tailings piles, is enclosed in slickentite.

Pfeiffer Mine (7)

The Pfeiffer mine is about 3 miles east of Latrobe on the south end of a ridge just west of the mouth of Little Indian Creek in sec. 7, T. 8 N., R. 10 E. Three small deposits were mined during World War I by Wm. Pfeiffer from open cuts, the largest cut being 30 feet long, 3 to 6 feet wide, and 10 feet deep. A small amount of prospecting was done with a bulldozer by Charles Immer in 1942, but no ore was mined. The workings indicate that the pods of ore that were mined trended about N. 30° E. and dipped almost vertically. The surrounding serpentine is highly sheared. The open cuts have caved and no ore can be seen in place, but dump specimens are of massive, medium-grained chromite. Logan (in Bradley 18), reported that about 80 long tons of chromite was mined from the property. All the deposits appear to have been worked out.

Brandon Mine (8)

The Brandon mine is on the crest of the ridge between Hungry Hollow and Indian Creek in sec. 12, T. 8 N., R. 9 E. During World War I the mine was operated by the Brandon brothers, but since 1918 the mine has been idle and the present ownership was not ascertained. Three open cuts from 10 to 25 feet long were made. All the cuts have sloughed badly and little of the geology remains to be seen in them. Apparently a series of pods, the largest of which was perhaps 10 feet long and 4 feet wide, were mined from lenses of somewhat sheared, serpentinized dunite. These dunite lenses were little more than thin shells around the chromite pods, and are surrounded by serpentinized saxonite. The chromite pods trended about N. 30° W. parallel to the strike of the enclosing dunite lenses. Contacts between the chromite and the dunite were sheared. Specimens of ore from the dumps are of massive, medium-grained chromite having a brilliant, almost vitreous luster. A small amount of kammererite is associated with the chromite. According to Logan (in Bradley 18) about 4 carloads of ore were shipped from the mine, but no record of this production appears in the Federal records. A very small amount of chromite remains in the bottom of the deepest cut, but reserves probably are small.

Bonetti Mine (9)

The Bonetti mine is about 3½ miles east of Latrobe and a few hundred feet northwest of Big Canyon Creek on land owned by the Bonetti brothers in sec. 7, T. 8 N., R. 10 E. Except for a small amount of scraping by a bulldozer in 1942 to determine the extent of the deposit, the mine has been idle since 1917. The workings dating from World War I comprise several small trenches and an open cut 55 feet long, 3 feet wide, and 2 or 3 feet deep. The lens of chromite explored by the larger cut is about 60 feet long and varies from 1 to 3 feet in width. It strikes N. 28° E. and dips 70° SE. The ore is rather low grade, and consists of chromite grains from 1 millimeter to 3 millimeters in diameter evenly disseminated in a matrix of hard, dense serpentinized dunite. The chromite grains are black and have a brilliant, almost glassy luster. No secondary chrome-bearing minerals are present. About 30 tons of ore is piled on the dumps. A few tons of ore was shipped to the Volo Mining Company's mills for tests in 1942, but the grade of the concentrates made proved to be too low to warrant further mining. Perhaps 200 tons of ore could be mined from the large lens. A small additional tonnage is available nearby in detached clots and small lenses of chromite similar in appearance and grade to that in the larger deposit.

Murphy Mine (10)

The Murphy mine is on a ridge 2 miles southeast of Latrobe in the SE¼ sec. 14, T. 8 N., R. 9 E. The property is owned by P. B. Murphy. About 3,000 tons of ore from this mine was milled during World War I, and in 1942 about 2,000 tons was mined by the Volo Mining Company and concentrated at its mill near Shingle Springs. The ore milled contained about 10 percent of Cr_2O_3. The workings comprise an area 250 feet long and 200 feet wide scraped by a bulldozer, several bulldozed open cuts beyond the limits of the scraped area, and two pits. The larger pit is 60 feet long, 20 feet wide, and 20 feet deep; the other pit, 40 feet above the larger pit, is 20 feet across and 15 feet deep.

The ore consists of chromite grains, ranging from one-fourth millimeter to 1 millimeter in diameter, disseminated in lenses of serpentinized but relative unsheared dunite. The ore carries 15 to 40 percent of chromite and averages about 20 percent. Layering is common in the ore and although there is considerable variation in the strike of layers in different ore lenses, the general strike is N. 20° E., and the dip of most layers is nearly vertical. Stringers of the low-grade ore in many places contain small clots of high-grade ore several centimeters long that are flattened parallel to the plane of the layering. Contacts of the ore with barren dunite are gradational and the rock has a tendency to break along the layers of higher grade ore.

The ore lenses range in width from 6 inches to about 4 feet, but they are not continuous for many feet along the strike as the ore feathers out into barren dunite in this direction. Although exposures are poor because much of the area is buried under piles of waste, the main zone of ore lenses appears to have a width of about 20 feet. Ore can be traced intermittently for about 200 feet along the trend of the main ore zone, and several outlying stringers of ore were seen beyond the lateral limits of this zone.

Both dunite and the surrounding saxonite are cut by chloritized diorite dikes that are from 3 to 24 inches wide.

No accurate estimate of reserves can be made, but the small, discontinuous nature of the ore lenses is unfavorable for the development of any large tonnage of ore. When Cater visited the mine in 1943 he estimated that on the basis of the ore exposed at that time not more than 1,500 tons of ore could be mined to a depth feasible for open pit operations.

Chaix Mine (11)

The Chaix mine is about 2 miles southeast of Latrobe and lies just east of the crest of a ridge in the NE¼ sec. 14, T. 8 N., R. 9 E. The property is owned by R. H. Chaix and was leased to C. D. Jones in 1943. Workings consist of five small open cuts 4 feet deep and 6 to 15 feet long; a large open cut 3 to 6 feet wide, 60 feet long, having a maximum depth of 14 feet; and several bulldozer cuts across the trend of the ore zone. All the workings except the bulldozer cuts date back to World War I.

The ore consists of disseminated and massive chromite contained in irregular, lenslike masses of serpentinized dunite, which in turn are enclosed by serpentinized saxonite country rock. The ore bodies are lenticular and commonly pinch and swell. At one place in the largest open cut the ore has a thickness of 4 feet, but the average thickness is about 18 inches. A series of chromite lenses is exposed for 215 feet along the zone of dunite masses, the ore, however, is rather discontinuous as the lenses pinch out entirely in places along the zone. The ore lenses strike about N. 20° E. and dip 70° SE., more or less parallel to the attitude of the enclosing dunite masses. Some irregular knots of chromite as much as 3 feet long occur beyond the lateral limits of the main zone of lenses. Most of the contacts of the ore with barren dunite are sheared, but locally they are undisturbed and rather sharply gradational. The chromite grains in the ore are 1 millimeter to 3 millimeters in diameter. Small amounts of uvarovite and kammererite are associated with the chromite. Several small dikes of pyroxenite cut the ore.

Taliaferro (in Louderback 18) reported that 220 long tons of ore was shipped from this deposit, an amount that seems reasonable, although the accredited production is only 81 long tons. Reserves of 300 long tons exist if the ore persists to a depth of 20 feet below the level of the present workings.

Smith Mine (12)

The Smith mine is in the NW¼ sec. 9, T. 8 N., R. 9 E., about three-quarters of a mile north of Latrobe. It is said that during World War I the mine was owned by a man named Schuler and was operated by another named Geisendorfer. In 1945 the property was owned by Ray, George, and Ellen Smith. The mine has been idle since World War I, but during that war considerable ore must have been produced, although no record of any production exists. A lens of chromite striking N. 40° W. and dipping vertically was mined from an open cut 100 feet long, 8 to 15 feet wide, and 10 feet deep. Ore consists of fine-grained chromite having an almost glassy luster. Talc and serpentine interstitial to the chromite make up 10 to 15 percent of the ore material. Minor amounts of uvarovite and kammererite also are present. Contacts of the ore lens apparently were intensely sheared, and the surrounding serpentine is soft and deeply weathered. About 20 long tons of chromite still remains scattered about the dump, but because the bottom of the open cut is covered with waste no estimates of other reserves could be made.

Ever Prospect (13)

Cameron (18) reported an occurrence of low-grade disseminated ore on the Ever Ranch in sec. 32, T. 9 N., R. 9 E., about half a mile from Cothrin Station. The occurrence was prospected by a shaft 12 feet deep and a number of trenches. Streaks and small lenses of disseminated ore striking north and dipping vertically are scattered sparsely over a zone 100 feet wide, but as Cameron says, ''Showing is only enough to justify more work.'' No ore ever has been shipped, and the property has been idle since 1918.

Other Deposits

One long ton of ore is reported to have been shipped from the Forni property 4 miles east of Latrobe. Michail Mundrini mined and shipped 16 long tons of ore from another deposit somewhere in the Latrobe area. The ore taken from both these properties was shipped in 1918, but nothing more is known concerning them.

Clarksville Area

Two groups of chromite deposits comprise the Clarksville area. One group lies about 2 miles northwest of the town and the other 2½ miles east of the town. The deposits northwest of Clarksville are the more important, and are the only ones in this area that have been worked since 1918. This northwest group comprises three deposits of disseminated ore occurring in a mass of serpentinized ultramafic rocks only a few hundred feet wide and about half a mile long. The known deposits east of town have been mined out, but intensive search might reveal other small deposits. The ultramafic rocks of the Clarksville area intrude various members of the Amador group. The area is one of low relief and rolling hills.

Dickson Mine (14)

The Dickson mine is in sec 4, T. 9 N., R. 9 E., on land owned by Mr. Dickson in Marble Valley 4 miles east of Clarksville. Chromite was mined from an open cut 20 feet long, 4 feet wide, and 4 feet deep. The deposit is in a lens of sheared dunite within saxonite a few feet southwest of the contact of the serpentine with metamorphic rocks. No ore remains in place, but the pod or pods that were mined apparently trended N. 60° W. parallel to the serpentine contact. A few pieces of massive, medium-grained chromite are scattered about the dump. Nothing is known about the production from this property, but it probably was small, and the deposit appears to be mined out.

Cowell Mine (15)

The Cowell mine is said to be west of the Dickson mine, but it could not be found. Logan (in Bradley 18) stated that about four carloads of chromite was shipped from the property by the Cowell Lime Company during World War I, but nothing further is known about the property.

Joerger Mine (16)

The Joerger mine is about 1½ miles northwest of Clarksville on the east slope of a low ridge near the south edge of sec. 35, T. 10 N., R. 8 E., on property owned by J. G. Joerger. The deposit has been worked from an open pit 150 feet long, 15 to 40 feet wide, and 25 feet deep. In addition to the pit, a number of bulldozer cuts have been made in prospecting for ore. Most of the work was done in 1942.

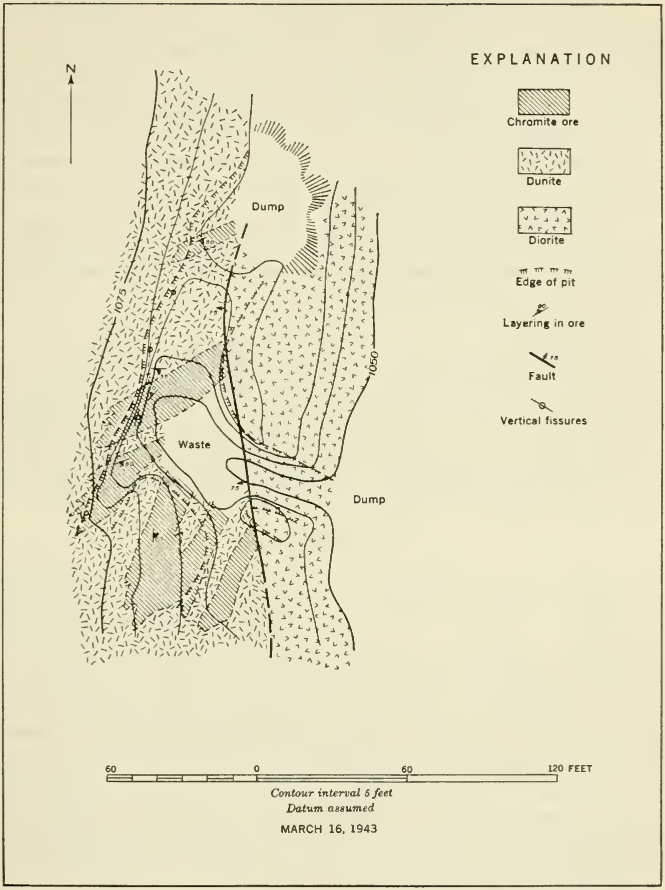
The deposit is on the east contact of a narrow lens of serpentine intruded into metamorphosed volcanic rocks of the Amador group. Five zones of low-grade disseminated ore 6 to 30 feet wide have been uncovered by the mining and exploratory operations (see fig. 3). These ore zones strike N. 25°-60° E. and dip either northwest or southeast at high angles. The ore zones have been cut off on the east by a diorite dike, which apparently was intruded along the contact between the serpentine and the metamorphic rocks; to the west the zones feather out into barren, serpentinized dunite. All contacts of the ore with barren dunite are gradational. The ore is conspicuously layered, and the layers are approximately parallel to the zones in which they occur. As a rule the ore tends to break along the layers of higher-grade material. Most of the chromite is uniformly fine-grained with individual grains averaging about 0.5 millimeter in diameter.

During World War I several hundred tons of milling ore was removed from this and the Walker mine, which adjoins on the north, and concentrated at the Geisendorfer mill. This ore was milled along with ore from the Murphy mine so the amount of concentrates derived from the Joerger and Walker ores is unknown. In addition to the milling ore mined during World War I a small amount of shipping-ore was cobbed from high-grade layers and sold. During 1942 several hundred tons of low-grade ore from the Joerger and Walker properties was milled with ore from other mines by the Volo Mining Company, so again the amount of concentrates made from the ores from each property is not known. The ore from the Joerger mine that was milled contained about 8 percent of Cr_2O_3.

Surface exposures indicate about 300 tons of ore per foot of depth, but because the ore bodies and the diorite contact converge, the areas of horizontal sections of the ore probably decrease with depth. From what he saw during his visit to the mine in 1945, Cater estimated that between 10,000 and 15,000 tons of ore containing 5 to 8 percent of Cr_2O_3 may remain in the deposit.

Walker Mine (17)

The Walker mine is in sec. 35, T. 10 N., R. 8 E. on the crest of the ridge a few hundred feet north of the Joerger mine. The mine is owned by F. E. Walker and was leased in 1942 to the Volo Mining Company. Workings comprise a shaft 60 feet deep; 30 feet of drift running 15 feet in opposite directions from the bottom of the shaft; two open cuts, one 50 feet long, 3 or 4 feet wide and 8 to 10 feet deep and the other one 30 feet long and 8 feet deep; several smaller pits and cuts; and an area scraped across the strike of the ore zone by a bulldozer.



Contour interval 5 feet
Datum assumed
MARCH 16, 1943

FIGURE 3. Sketch map of the Joerger mine, El Dorado County, California.

The ore is very similar to that on the Joerger property, and consists of fine-grained disseminated chromite in alternating layers of high- and low-grade material. In general the layering in the ore is parallel to the attitude of the ore zone, strikes about N. 35° W. and dips very steeply eastward. The ore zone is 3 to 4 feet wide, and is exposed along the strike for 100 feet and down the dip for the full length of the shaft. The matrix of the ore and the enclosing wall rock is serpentinized dunite; most of the surrounding country rock is serpentinized saxonite. The chromite has a brilliant, almost glassy luster.

According to Taliaferro (in Louderback 18), three carloads of carefully sorted ore was shipped from the property in 1917, and in the following year several hundred tons of low-grade ore was treated at the Geisendorfer mill. However, no record was kept of the quantity of the concentrates made from the ores from the various mines that supplied the mill, so the production from the Walker mine is included in the output listed for the Murphy mine.

Perhaps 1,500 tons of ore remains in the main ore body to the depth of the shaft, and an indeterminate amount below that level. Most of this ore contains only 10 or 12 percent of Cr_2O_3.

About a quarter mile north of the main Walker mine workings are a small open cut and a pit which expose a small amount of ore similar to that found in the main workings. This smaller deposit was described by Taliaferro as the Miller property (18).

Simpson Mine (19)

The Simpson mine is 9 miles east of Folsom in sec. 13, T. 10 N., R. 8 E. The following description is quoted from Logan (in Bradley 18): "Lenticular bodies of chrome ore occur, along a contact of serpentine and schist, striking NS. and dipping 55° E. An ore body being worked was 28″ wide, 16′ long and 20′ deep with ore exposed in the bottom. A 12″ body of ore had been traced by shallow shafts for a distance of 75′ northward and 200′ southward." The total production was 54 tons of ore, which was shipped by Fleishbein and Kinney in 1917.

Flagstaff Hill Area

More than three-quarters of the chromite shipped from El Dorado County has come from deposits in an elongate, northward trending mass of ultramafic rocks in the relatively small Flagstaff Hill area located in Townships 10 and 11 N., R. 8 E., on the western edge of the county. The principal commercial and shipping centers near the area are Auburn, on the main line of the Southern Pacific Railroad Company and U. S. Highway 40 about 6 miles to the north, and Folsom, on the Sacramento and Placerville Railroad and U. S. Highway 50 about 7 miles to the southwest. Numerous private dirt roads and truck-trails make nearly all parts of the area readily accessible from the paved but narrow and circuitous Auburn-Folsom county road that traverses the area from north to south. Parts of these roads will be inundated by the waters to be impounded by the Folsom Dam, but access to the area will not be impaired seriously and the haulage distance via other adjoining county roads will not be increased by more than a mile or two.

The area lies in the low western foothills of the Sierra Nevada between the North and South Forks of the American River. The most prominent topographic feature of the area is a long, narrow dissected ridge underlain by the ultramafic mass. Flagstaff Hill, the highest point on the ridge, rises to an elevation of 1,421 feet above sea level or nearly 1,030 feet above the bed of the river nearby. Dense growths of manzanita, chemisal, and scrub oak cover most of the hilly parts of the area, especially those parts underlain by ultramafic rocks. The climate is mild and semiarid. Water for large-scale mining and milling purposes must be pumped from the river.

General Geology

In addition to having the largest production record of any area in the county, the Flagstaff Hill area also has the largest potential chromite reserve; consequently, it has been investigated more thoroughly than any other area. The geology of about one-third of the ultramafic mass, that part including the Pillikin mine, was mapped and described in considerable detail by Wells, et al (40). Parts of the Pillikin mine were remapped in detail and several other mine areas were studied by the authors in 1942-43. The geology of these mine areas is described in detail elsewhere in this report. In order to complete the geologic map of the area, a few days were spent in the field in 1949 by Rynearson. The results of this field work were combined with the previous detailed mapping to form plate 9, which shows the salient geologic features of the area as a whole. Although many details of the complex geology remain to be studied, the general features are presented in this report.

The oldest rocks in the area are metamorphosed volcanic and sedimentary rocks. Although no attempt has been made to subdivide this assemblage of rocks on the map (pl. 9), the hornblende and chlorite gneisses and schists adjacent to the mass of ultramafic rocks probably belong to the Amador group of Jurassic age, whereas the rocks that include the limestone lenses in the NW corner sec. 15 may belong to the Calaveras formation, which is thought to be of Carboniferous age or older. Wells (40) described the metamorphic rocks as follows:

"The most abundant of the metamorphic rocks consist mainly of hornblende and feldspar and are medium- to coarse-grained, with either a schistose or a gneissic structure. The hornblende and feldspar form spindle-shaped aggregates arranged in distinct lines that pitch directly down the dip of the foliation. These hornblende rocks appear to have been originally andesitic or dioritic in character; they may be intrusive but are more probably effusive in origin.

"Interlayered with these coarse-grained schists and gneisses are finer-grained chlorite schists with metacrysts of amphibole or, more rarely, of pyroxene. Black, fine-grained hornblende schist, with lenticular epidote patches, is present in subordinate amounts." Some schistose quartzite is interlayered with hornblende and chlorite schists in the NW¼SE¼ sec. 16, and lenses of commercial-grade limestone occur in the NW¼ sec. 15.

Intrusive into the metamorphic rocks is a heterogeneous mass of ultramafic rocks. The exposed part of this mass is approximately 5½ miles long with a maximum width of a little more than 1 mile. The bulk of the mass is roughly tabular in shape, having a strike about north and a dip 65°-75° E.; the long axis appears to plunge northward at a low angle. A long, narrow appendage to the main mass extends southwestward from the SW corner sec. 21. The relationship of these two elements of the mass to each other and to the structure of the enclosing rocks is not clear; the bifurcated shape of the outcrop of the mass and the conformity of its contacts with the foliation of the surrounding rocks suggests that it occupies an unbalanced position in a northward plunging anticlinal structure.

Intense alteration, especially silicification, and local shearing in many parts of the ultramafic mass have obscured the original character and distribution of the component rock types. Nevertheless, irregular bodies of dunite, lherzolite, pyroxenite, and layered olivine and pyroxene rock; dikes of metadiorite; and irregular masses of the altered equivalents of all these rock types can be recognized and have been mapped in parts of the area. In general, the southern part of the mass consists mainly of pyroxenite and small scattered bodies of dunite; the east-central part consists mainly of lherzolite; the west-central part consists of relatively large bodies of dunite and small, scattered bodies of pyroxenite and layered olivine and pyroxene rock; and the northern part consists mainly of highly altered dunite, though much lherzolite and a little pyroxenite may be represented also.

As noted above, the borders of the ultramafic mass are parallel, or nearly so, to the foliation of the adjacent metamorphic rocks. The eastern contact with the metamorphic rocks is relatively sharp and well defined, as is the southern part of the western contact. The northern part of the western contact and both contacts at the northern end are quite indefinite. In these areas the margins of the ultramafic mass grade outward and upward into a zone of mixed rocks formed by the lit-par-lit injection of numerous small lenses and thin sheets of ultramafic material along the foliation planes of the metamorphic rocks. Plate 9 shows the approximate extent of the injection complex zones. The metamorphic rocks adjacent to the small injected masses of ultramafic rock have been altered to gneissic material containing metacrysts of pyroxene, chlorite-epidote rock, garnet-chlorite rock, or talc-chlorite rock. In most places the original character of the injected ultramafic material is hardly recognizable, as it is completely altered to talc-chlorite or talc-serpentine rock. In a few places, notably where chromite occurs as small masses or as narrow zones or layers of disseminated crystals, it is evident that the original rock was dunite.

The internal stuctures of the ultramafic mass and the alteration of the rocks are discussed in more detail under the description of the Pillikin mine.

The gray, medium-grained granodiorite in the northwestern part of the area represents the eastern margin of a large mass that extends north almost to Auburn, south almost to Folsom, and west for at least 7 or 8 miles. This granodiorite probably is an outlier of the main Sierra Nevada batholith. According to Wells (40), "A typical specimen contains about 45 percent of andesine (near An ^{35}), 20 percent of quartz, 10 percent of orthoclase, 10 percent each of green hornblende and brown biotite, and accessory titanite, magnetite, apatite, and zircon. The average grain size is 1 millimeter or 2 millimeters, although some plagioclase crystals are as much as 4 millimeters long." The granodiorite clearly is later than the metamorphic rocks, which it intrudes, and almost certainly is later than the ultramafic rocks. It is separated from the exposed parts of the ultramafic mass and the injection complex of ultramafic and metamorphic rocks by a continuous septum of metamorphic rocks. Lindgren (94) mapped a small inclusion (?) of serpentine in the granodiorite near the river on the west edge of sec. 16 that probably represents a separate outlying mass of ultramafic rock that was engulfed by the granodiorite. Although the contact of the granodiorite appears, on a broad scale, to cut across the foliation of the metamorphic rocks, the contact and the foliation are nearly parallel in the area mapped. At or near the contact the granodiorite has a more or less obscure gneissic structure, and in some places it grades almost imperceptibly into the metamorphic rocks. The irregular zone of hybrid rocks along the contact in the SE corner sec. 20 was formed by the lit-par-lit injection of granodiorite material along the planes of foliation of the metamorphic rocks.

Plate 9 shows several small deposits of Quaternary alluvium and soil in the part of the area mapped in detail by Wells, et al. No attempt was made to deliniate similar deposits of alluvium and soil in other parts of the area or to show the deposits of both early and late sands and gravel that occur along or near the forks of the American River.

More than 150 separate occurrences of chromite have been prospected or mined in the Flagstaff Hill area. The locations of most of these are shown on plate 9. Not shown are several small prospects just south of the border of the map but north of the South Fork of the American River. Many of the chromite occurrences opened so far have been too small or too low in grade to be mined profitably. A few deposits, particularly those on the Pillikin mine property, have yielded appreciable quantities of chromite in the past and some yet contain large tonnages of low-grade milling ore. The principal mines are described below.

Pillikin Mine (23)[2]

Location, History, and Production. The Pillikin mine proper is in secs. 21 and 28, T. 11 N., R. 8 E., in the central part of the Flagstaff Hill area. The property includes the NE¼, SE¼, and SW¼ sec. 21, the W½NE¼ and NW¼ sec. 28, and the SE¼NE¼ and W½NE¼ sec. 29, all owned by the Pillikin Syndicate, Mr. C. P. Carruthers, Trustee. In addition to the Old Pillikin workings, the present property embraces the Placer Chrome Company workings in the NE¼ sec. 21 and the Nielson mine in the NE¼SE¼ sec. 21. Three other groups of deposits, those in area 6 and part of area 7 on the property of the Steele Estate and those in area 8 on the property of the Zantgraf gold mine (see pl. 9), are described hereunder because they are geologically and geographically related to deposits on the Pillikin property. Several small deposits in the NE corner sec. 21 are also included under the description of area C of the Dobbas mine.

Chromite was known to exist in the area as early as 1853, and Lindgren (94) reported that a few pockets of chromite had been worked previously to 1894. There was no notable production until World War I, when the Noble Electic Steel Company leased a part of sec. 28 from George Pillikin and worked the deposits from 1915 to 1918. Most of the chromite produced during this period was in the form of lump ore, but a small mill was constructed and some concentrate was made in 1918. After 1918 the property was idle from 1918 until 1936, when it was acquired by U. S. Chrome Mines, Inc. This company constructed a new 200-ton concentrating plant (see pl. 12) near the site of the old mill and operated the property from 1937 to 1939. The Rustless Mining Corporation leased the property in February 1940 and carried on large-scale mining and milling operations until it relinquished its lease in September 1942. Except for the mining the small amounts of shipping-grade ore, all mining and milling operations were suspended on January 6, 1943. In 1944 the Pillikin Syndicate acquired the property, and in

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[2] In some previous reports Pillikin has been spelled "Pilliken", however, Mr. George Pillikin, the man for whom the mine was named, spelled his name with an "i" instead of an "e" and his spelling is used in this report.

1945 J. J. Taylor obtained a lease from Mr. Carruthers and mined a small amount of shipping-grade ore. The Pillikin deposits have yielded a total of 27,144 long tons of chromite (see table 2).

Table 2. Production of Pillikin mine (excluding areas 5 and 9)

Year	Type of ore	Ore shipped (long tons)	Grade (percent Cr_2O_3)	Remarks
1916	Shipping ore	2,137		
1917	do	3,398	43	
1918	Shipping ore and some concentrates	3,624		
1919-1930				No production
1931	Concentrating ore (?)	10		
1932-1935				No production
1936	Concentrating ore (?)	30		
1937	Concentrates	464	50	
1938	do	759	49	
1939	do	3,036	45-48	
1940	do	1,772	42	
1941	do	4,418	42	
1942	do	6,991	41-43	
	Shipping ore	70		
1943	Shipping ore	273	43	
1944				No production
1945	Shipping ore	162	44	
Total		27,144		

Basis of Information. Except for areas 3 and 4, known respectively as West Basin and Chrome Gulch, the information contained herein is largely a resume of U. S. Geological Survey Bulletin 922-0, Chromite Deposits of the Pilliken area, El Dorado County, California, by F. G. Wells, L. R. Page, and H. L. James. Field work for Bulletin 922-0 was done in the fall of 1939 by a party under the supervision of F. G. Wells. Extensive mining and development work on some of the deposits subsequent to this investigation afforded opportunities for more detailed studies and large-scale topographic and geologic maps of the West Basin and Chrome Gulch areas were prepared by G. A. Rynearson, F. W. Cater, Jr., and D. H. Dow between December 1942 and February 1943. Descriptions of these areas are based on the later investigation.

Geology. Although the ultramafic rocks have been highly serpentinized and otherwise altered, four varieties of the original rocks have been recognized and mapped (see pl. 9). Dunite, lherzolite, pyroxenite, and layered olivine and pyroxene rock occur in irregular zones that parallel roughly the long axis of the ultramafic mass; this zoning is rather obscure in intensely altered areas. The largest dunite bodies are in the western part of the Pillikin area, but many thin layers and small irregular bodies of dunite occur elsewhere. Lherzolite, the most abundant of the ultramafic rocks, underlies most of the eastern two-thirds of the area and occurs elsewhere as small irregular masses, especially in the southwestern part of area 3. Small masses of pyroxenite and layered olivine and pyroxene rock in close association with dunite are common in the western part of the area but are not known to occur in the lherzolite.

Two systems of dioritic dikes, one system trending northeast and the other northwest, cut the ultramfic rocks. Dikes belonging to the northeast-trending system have been extensively altered to dark green talc-chlorite schist, but all gradations from apparently unaltered, hard, fine-grained diorite to talc-chlorite schist occur. Dikes of the northwest trending system commonly are almost unaltered and may cut the schistose dikes, though no direct evidence of this relationship was found. Some of these dikes appear to be quartz diorite, a rock not recognized in dikes of the other system.

Widespread hydrothermal alteration of the ultramafic rocks has been of great importance both geologically and economically. The following is quoted from Wells (40):

> "The peridotites—both dunite and lherzolite—have every where been altered slightly, and in large areas completely replaced, by hydrothermal agencies. The pyroxenites, on the contrary, are little altered. Four types of alteration, listed in order of their extent, have been recognized: (1) serpentinization, (2) silicification, (3) the formation of talc, and (4) the formation of magnesite. Alteration, especially to talc, has been most intense along shear zones. Serpentinization probably took place during the late magmatic stage of the early igneous cycle. Talc and magnesite probably were formed a little later, and their formation was controlled by structural features."

Silica, talc, and/or magnesite may be formed by several chemical reactions involving the decomposition of serpentine by either carbonate or siliceous waters or both. The product or products resulting from such reactions vary mainly with the composition and physical character of the rock being altered, the composition of the solutions, and the temperature. Talc so formed usually is deposited at or near the point of alteration, but silica and magnesite commonly are carried off by the solutions and deposited elsewhere.

The silicification results from two processes: first, hydrothermal activity mainly along fissures and shears, and second and more commonly, supergene replacement of serpentine masses of considerable size and thickness. One of the best examples of hydrothermal silicification in the area is described by Wells (40) as follows: ''The fissure of the northeast-southwest fault in section 28 contains a four-foot vein of milky quartz where its footwall is of schist, but is followed only by a zone of silicified dunite and talc schist where both its walls are of ultrabasic rocks. It seems probable, therefore, that the incompetent ultrabasic rocks were unable to hold large spaces open, so that the silica deposited in them took the form of fine-grained cherty masses rather than vein quartz.'' Silicification by supergene replacement produces rocks that range from slightly silicified dunite, lherzolite, and pyroxenite to deep red, hard jasperoid in which all the original minerals have been replaced. Such areas of silicification appear to be the result of a leaching and weathering process related to an earlier erosion surface. Silica is released from serpentine and other ferromagnesian minerals by chemical decomposition effected by surface waters and, as silica is only slightly soluble, it is mostly carried in the ground water as colloidal suspension. These colloidal solutions or suspensions are unstable and the silica readily separates from them as a gel. If the gel is allowed to dry out and the silica crystallizes it becomes relatively insoluble to subsequent solution. This type of silicification most commonly takes place in ground that is wet part of the year and dries out during the dry season. Silica gels having consistencies that range from unctuous jellies to hard, brittle opaline substances are being formed at the present time and are rather common as fissure fillings in many of the mine workings.

Removal of silica from serpentine by solutions containing an excess of CO_2, is accompanied by the formation of magnesite, or hydromagnesite. The creamy white, fine-grained, and in some places laminated veins of magnesite such as are exposed in Shovel Pit No. 3 of West Basin (see pl. 13) are undoubtedly of hydrothermal origin, but apparently magnesite also is formed by weathering processes. The delicate magnesite crystals that occasionally line cavities and open fissures are believed to be of supergene origin; large quantities of magnesite-cemented stream gravels are common in serpentine areas elsewhere in California where hydrothermal magnesite appears to be almost or totally lacking.

A little talc is present throughout most of the dunite and lherzolite, especially along faults and shear zones, and several large masses of talc schist have been formed at the expense of these rocks. (see pl. 9).

Silicification makes the rocks very hard and difficult to mine and crush, but other alterations soften the rocks and simplify the mining and milling procedures. Silicification of the ore, though not affecting the chromite itself, tends to "lock" the chromite grains in the gangue, which necessitates finer crushing and thereby increases the amount of sliming.

Numerous faults, both large and small, cut the area. The largest fault mapped strikes about N. 25° E. across sec. 28 with a dip of 60° SE. The contact of the ultramafic and metamorphic rocks is offset more than 2,000 feet along this fault. Other large faults displace contacts a few hundred feet. Within the ultramafic mass, contacts and ore layers are offset by many small faults having displacements of only a few feet or a few tens of feet.

Chromite Deposits. Disseminated grains of chromite are distributed throughout the dunite in concentrations of less than 0.5 percent to more than 30 percent, and in the lherzolite in concentrations rarely exceeding 1 percent. Concentrations of chromite large and rich enough to mine are found only in dunite. Most workable deposits of disseminated chromite are schlierenlike zones in which the ore has a banded appearance due to alternating chromite-rich and chromite-poor layers. A few ore bodies, however, consist of evenly disseminated chromite in which layering is inconspicuous or absent. In some workings, lenses and layers of nearly pure chromite occur with thicknesses ranging from a fraction of an inch to about 4 feet. Many of these were selectively mined as shipping-grade ore. Small amounts of nodular ore have been found in West Basin, north of Chrome Gulch, and in the Placer Chrome Company workings. Most of the milling-grade ore comes from zones in which layers and clots of massive chromite are associated with disseminated chromite. Ore zones and the layering within the zones commonly lie parallel to the trend of the enclosing dunite bodies and to the trend of the entire ultramafic mass, but local variations, the result of magmatic flowage and later shearing, are numerous.

Bodies of disseminated ore may or may not have sharply delineated boundaries. In most places where contacts are normal and unsheared, the ore bodies grade into barren dunite with gradual decreases in the concentration of chromite, but in some places boundaries are sharp. As a rule layers of massive chromite have rather sharp lateral boundaries, but pinch out either gradually or abruptly, or frazzle out into streaks of disseminated grains along the strikes. Layers of massive chromite commonly pinch and swell in thickness.

Individual chromite grains vary considerably in form and size. Wells (40) states:

> "Most of the disseminated grains have more or less definite crystal form, but some are rounded at the corners as if corroded. Some grains are rounded at one end but not at the other, and many are completely rounded. Some clusters of irregular grains appear to have filled up spaces between crystals of other minerals; some have the shapes of coalescing globules. Some grains have curved cracks, which may indicate that they grew from a rounded nucleous. Chromite grains of all shapes enclose gangue minerals and are enclosed by them. Some grains in sheared rocks have eyelike outlines and tail out into thin streaks of dust along the foliation."

In general, the smaller grains and the grains in the leaner ore have better formed crystal outlines. Euhedral grains are less common and rounded grains are more common in the layers of richer ore. Grains of chromite vary considerably in size, ranging from 0.2 millimeter to 2.0 millimeters in diameter. As a rule, the richer the ore the larger the grain size, but in bands of massive ore the grains are intergrown. In nodular ore the individual nodules are sharply bounded but may enclose grains of olivine and serpentine.

Concentrations of chromite vary enormously in size and may range from small schlieren weighing a few pounds to masses that may contain 300,000 tons. However, all such concentrations cannot ordinarily be considered ore, inasmuch as the grade of disseminated ore varies greatly over short distances and lenses of high grade ore are of irregular size and distribution. These factors greatly complicate delimiting volumes of any particular grade of ore, but many ore zones containing over 5 percent of Cr_2O_3 are known to be of considerable extent. From one such zone more than 37,000 tons of ore containing an average of 11 percent Cr_2O_3 has been mined since 1937 in addition to a large but unknown tonnage mined during World War I. Perhaps the largest single ore body is in Chrome Gulch, but it has been exploited only to a small extent. Most of the deposits mined have produced only a few thousand tons of ore containing from 5 to 10 percent of Cr_2O_3. Lenses of high-grade ore containing from 40 to 50 percent Cr_2O_3 may be more or less continuous along their strike length for distances of more than 100 feet and have maximum thicknesses of 4 feet. A total of nearly 10,000 long tons of such shipping-grade ore has been produced.

With a few exceptions the chromites in the various ore bodies of the Pillikin mine apparently have comparatively small ranges in composition. The abnormal variations indicated in the analyses tabulated below may be due to the presence of discrete grains of magnetite in the ores and concentrates, but this possibility has yet to be confirmed by additional laboratory study (see tables 3 and 4).

Results of some laboratory studies by the Rustless Mining Corporation during its milling operations suggest a relation between the grain size and the composition of the chromite. As a rule, the coarser grains are richer in chromic oxide than the smaller grains; however, these compositional variations cannot be distinguished in the field. Possibly some of the finer grains are accessory magnetite or magnetite derived from the serpentinization of olivine. In support of this possibility, it should be

Table 3. Partial analyses of ores and concentrates from the Pillikin mine (R. E. Stevens and M. K. Carron, analysts)

Sample*	Ore			Concentrate			
	Percent chromite in specimen	Percent Cr_2O_3	Percent Cr	Percent Cr_2O_3	Percent Cr	Percent Fe	Cr-Fe ratio
FGW-87-40	45	23.5	16.1	52.32	35.80	17.39	2.06
FGW-88-40	25	1.7	1.2	6.67	4.57	62.28	.07
FGW-92-40	31	16.6	11.4	54.30	37.17	18.31	2.01
FGW-90-40	81	45.3	31.0	55.84	38.21	14.04	2.72
FGW-89-40	31	16.3	11.1	52.77	36.09	16.61	2.17
DHD-1-43	59.2[1]	32.63	22.32	55.06	37.69	14.90	2.53
DHD-2-43	30.6[2]	16.34	11.18	53.46	36.59	18.79	1.95
DHD-3-43	90.8[1]	50.19	34.33	55.17	37.85	15.47	2.45
DHD-4-43	30.2[2]	15.71	10.75	52.13	35.66	18.36	1.94
DHD-5-43	2.3[3]	1.06	0.73	46.2	31.6	26.5	1.19
DHD-6-43	73.1[1]	39.57	27.08	54.18	37.07	17.04	2.17
FGW-86-40	82	44.1	30.2	54.07	37.01	14.13	2.62
FGW-91-40	63	34.1	23.3	54.45	37.27	17.45	2.14
GAR-11-43	11.6[4]	4.64	3.18	40.02	27.39	32.21	.85
GAR-14-43	8.9[5]	3.08	2.11	33.91	23.21	39.20	.59

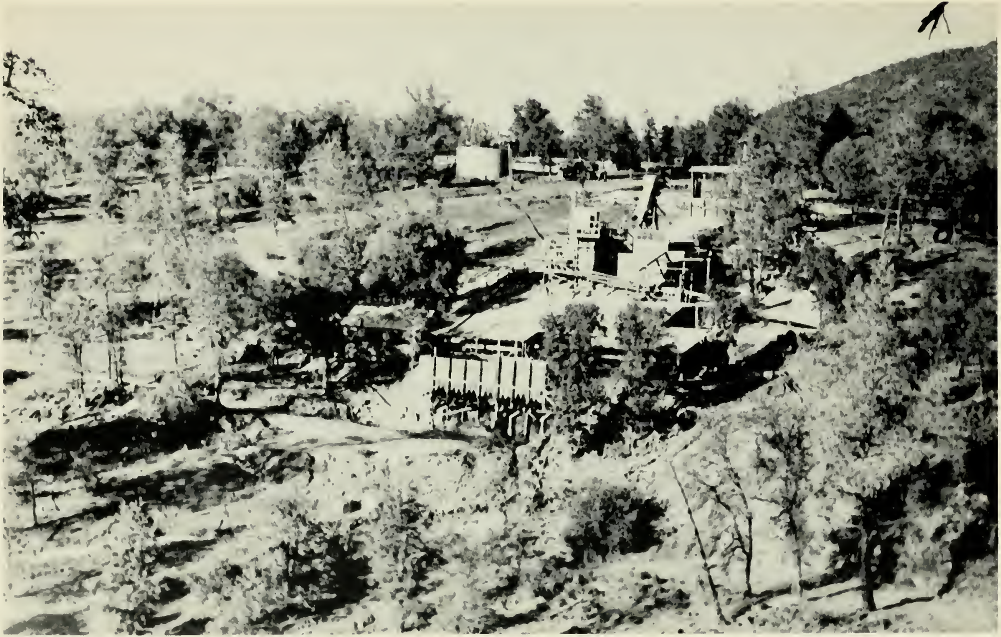
[1] Nonmagnetic.
[2] Very slightly magnetic.
[3] Moderately magnetic.
[4] Contained strongly magnetic fraction.
[5] Strongly magnetic.

* FGW-87-40	Ore from pit 5A, area 2, East Basin.
FGW-88-40	Low-grade ore from pit 5A, area 2, East Basin.
FGW-92-40	Disseminated ore from south end of pit 6, area 2, East Basin.
FGW-90-40	High-grade ore from pit 3, area 3, West Basin.
FGW-89-40	Disseminated ore from pit 3, area 3, West Basin.
DHD-1-43	Disseminated ore from pit 3, area 3, West Basin.
DHD-2-43	Disseminated ore from pit 3, area 3, West Basin.
DHD-3-43	High-grade ore from pit 2, area 3, West Basin.
DHD-4-43	Disseminated ore from pit 2, area 3, West Basin.
DHD-5-43	Disseminated ore from pit 2, area 3, West Basin.
DHD-6-43	Disseminated ore from cut 750 feet south of pit 1, area 3, West Basin.
FGW-86-40	High-grade ore from area 4, Chrome Gulch.
FGW-91-40	Disseminated ore near north shaft, area 4, Chrome Gulch.
GAR-11-43	Chip sample across west ore body, area 4, Chrome Gulch.
GAR-14-43	Chip sample along trench in east ore body, area 4, Chrome Gulch.

Table 4. Analyses of cleaned chromite concentrates from the Pillikin mine (R. E. Stevens and M. K. Carron, analysts)

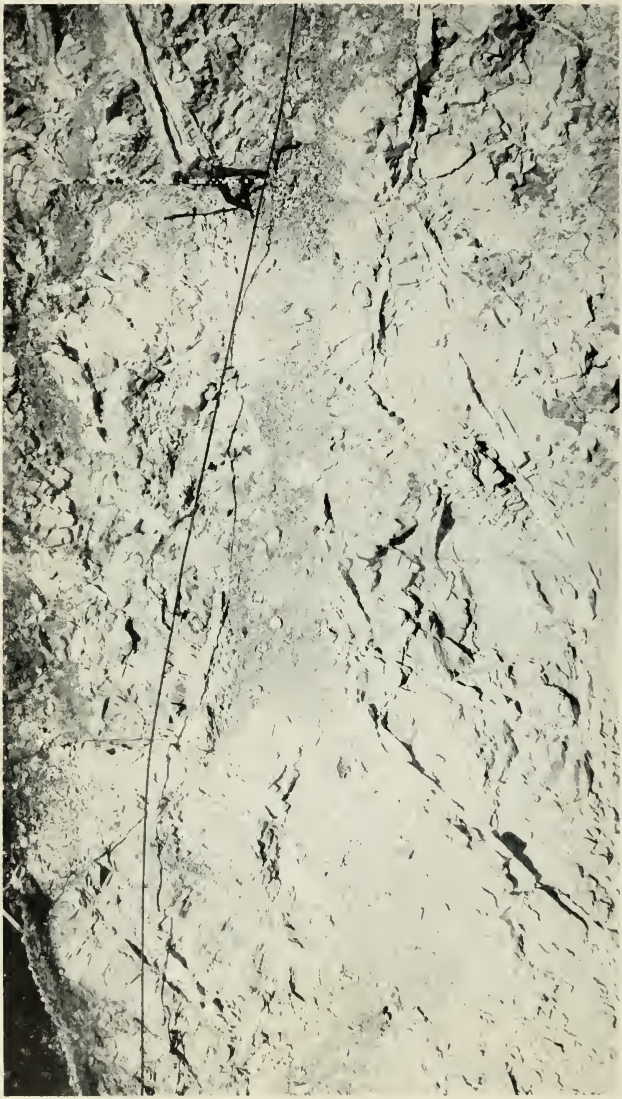
	FGW-89-40* (percent)	FGW-90-40* (percent)	FGW-91-40* (percent)
Cr_2O_3	52.77	55.84	54.45
Al_2O_3	10.31	10.75	7.90
Fe_2O_3	9.99	6.19	7.90
FeO	12.40	12.49	15.34
MgO	12.10	13.54	12.60
MnO	0.32	0.27	0.27
CaO	0.16	0.16	0.06
TiO_2	0.17	0.18	0.23
SiO_2	0.92	0.52	0.90
H_2O+	0.76	0.40	0.38
Total	99.90	100.34	100.03
Cr-Fe ratio	2.17	2.72	2.14
Specific gravity		4.415	4.412
Impurity	Olivine	Serpentine	Serpentine

* Concentrate panned from sample number shown. See footnote to table 3 for locality of sample.



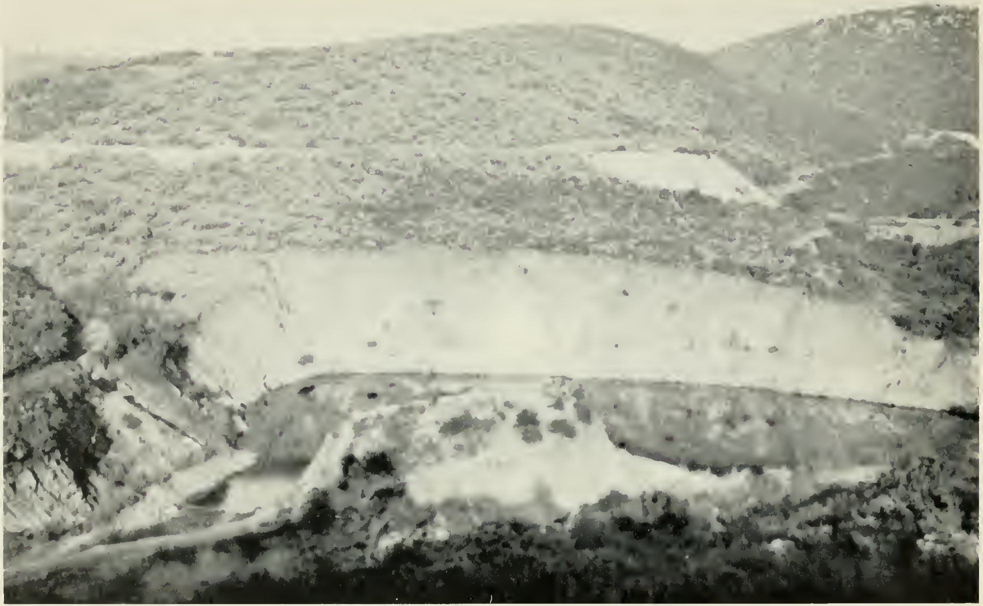
CHROMITE CONCENTRATING PLANT

Operated by U. S. Chrome Mines, Inc. and Rustless Mining Corporation at the Pillikin mine, El Dorado County, California.

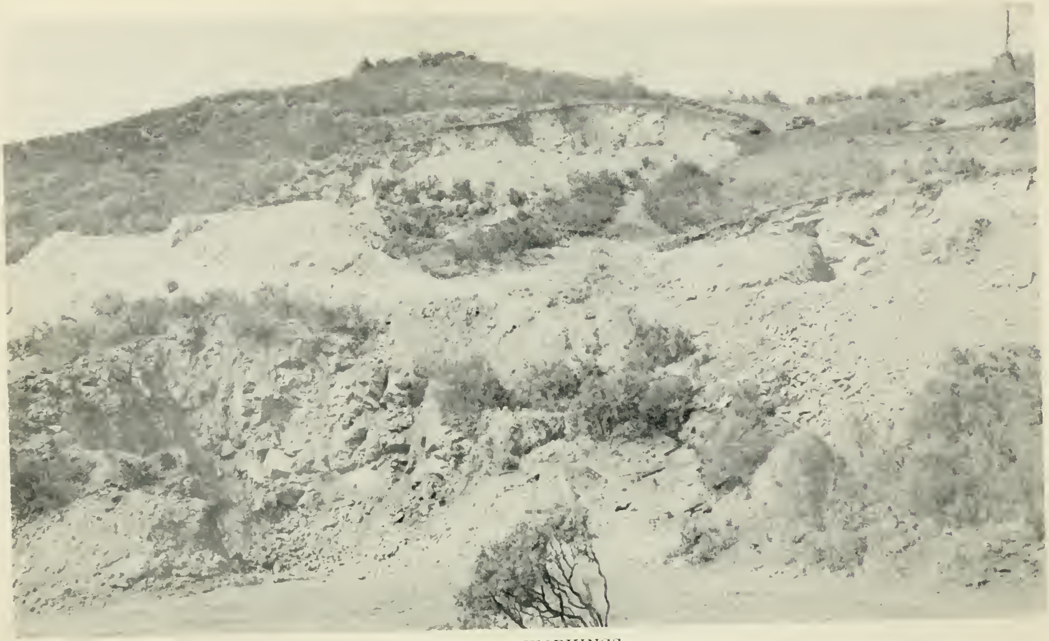


PILLIKIN MINE

North wall of Shovel Pit No. 3 in area 3, West Basin. Note the network of magnesite veins cutting the serpentine. *Photo by F. G. Wells, 1939.*



VIEW ACROSS LARGE WATER-FILLED PIT
In area 1, East Basin, Pillikin mine, El Dorado County, California.
Camera facing northeast.



OPEN PIT WORKINGS

In area 3, West Basin, Pillikin mine, El Dorado County, California. View north towards Shovel Pit No. 3 (top center).

Photo by C. V. Averill, May 1941

noted that concentrates made from some of the ores are strongly magnetic and contain an appreciable magnetic fraction. However, not all of this magnetic material is magnetite, for some of the chromite, supposedly that higher in iron, is magnetic. Furthermore, higher-grade ores usually yield concentrates with a lower percentage of contained iron than do lower-grade ores. This result would be expected if the ores contain a small but relatively constant amount of free magnetite.

On the average, concentrates of the Pillikin ores have contained about 43 percent Cr_2O_3 and have had chromium-iron ratios ranging from 1.3 to 2.3. Preliminary tests seem to indicate that the concentrates could be improved by removal of at least part of the magnetic fraction by some method of magnetic separation. The shipping-grade ore that has been mined also have averaged about 43 percent Cr_2O_3.

Owing to the highly irregular shapes and distribution of chromite ore bodies estimates of reserves for other than measured ore are subject to large margins of error. Reserves of measured ore are small, and are included in estimates of indicated reserves. For this report indicated ore reserves were estimated from exposures at the surface, from underground workings, and from projections for reasonable distances on geologic evidence. Relatively few assays are available for use in estimating the grade of reserve ores. In most cases estimated percentages of Cr_2O_3 have been derived, on the basis of a few comparative assays, from visual estimates of the chromite content of the ores. A cutoff grade of 5 percent of Cr_2O_3 generally was used when the Pillikin mill was in operation, therefore, chromiferous rock containing an average of less than 5 percent was not considered in estimating reserves for this report.

About 450,000 tons of material containing 5 percent or more of Cr_2O_3 are indicated in the Pillikin deposits at depths permitting open pit operations. It should be emphasized, however, that some of this material is in bodies too small to be mined economically. Potential reserves may be very large; and it is not unreasonable to assume, indeed, that ore bodies may be scattered throughout the bulk of the ultramafic mass, but, of course, many of them would be at depths of thousands of feet. No geologic control for the localization of chromite bodies in this area, other than their occurrence in dunite, has been recognized thus far, and in lieu of such information the success of drilling and other exploratory work for buried ore bodies is largely a matter of chance. Under price conditions prevailing in the past the cost of finding and mining ore bodies not exposed at the surface has been prohibitive.

Ore-Bearing Areas

The same reference numbers are used in this report for the designation of chromite-bearing areas as were used in Bulletin 922-0. Area 3, West Basin, and Area 4, Chrome Gulch, are described in some detail, and briefer descriptions of the other areas are included.

Area 1, East Basin. Area 1, or East Basin, is in the SW¼NE¼ sec. 28, T. 11 N., R. 8 E. A large open pit about 400 by 400 feet across has nearly obliterated the old underground workings (see pl. 14). Although much ore remained in the bottom of the pit, mining was abandoned when the walls of the pit became too high and steep for safe, economical operations. Water rapidly flooded the pit so the area was not remapped by the Survey party working in the area in the winter of 1942-43.

The area is underlain by a dunite mass about 2,000 feet long and 1,000 feet in maximum width, which lies between two pyroxenite masses to the east and west. The dunite is bound on the northeast and northwest by a silicified area and is cut off on the south by a large fault trending N. 25° E. It is altered to soft light-colored serpentine and talc with minor amounts of magnesite.

The ore occurs as disseminated chromite and irregular lenses of nearly pure chromite; most of the early mining was confined to the high-grade lenses. Individual layers and lenses of ore strike N. 10° W. to N. 50° E. and dip 40° to 80° E., but the general trend of the ore zones is N. 10° W. and the average dip is 60° E. Zones and small masses of ore are scattered over much of the pit but a large proportion of the material excavated contained very little chromite. The ratio of waste to ore was approximately 8 to 1.

Several barren bulldozer trenches south of the pit preclude a surface extension of the ore zone in this direction, but a narrow band of ore can be traced a short distance north of the pit and indicates the possibility of developing a small amount of ore in this direction. The Rustless Mining Corporation mined 37,110 tons of ore averaging 11 percent of Cr_2O_3 from the pit. Any estimation of ore reserves must await drainage of the pit.

Area 2, Bonanza King Mine. The chromite deposits in area 2, in the NW¼SW¼ sec. 28, were worked from two large open pits and some underground workings. The early undeground workings, opened by the Noble Electric Steel Company during World War I were known as the Bonanza King mine. The large pits were developed later by U. S. Chrome Mines, Inc. and the Rustless Mining Corporation. The larger open pit, called pit 5, is flooded to the level of the Chrome Gulch tunnel, which opens into the north end of the pit. The smaller pit is called 5A and lies south across the highway from the main pit.

It is probable that all the workings are on one ore zone. The ore mined from pit 5 consisted of three more or less distinct zones of layers, lenses, and stringers of both disseminated and nearly massive chromite. In places the individual lenses of ore had a thickness of about 5 feet. The ore mined from pit 5A was similar, but the three zones were less distinct. Most of the ore appears to have been mined out of pit 5A, but some ore still remains in the north and south walls and bottom of pit 5. Some of the higher-grade ore north of pit 5 has been selectively mined from the underground workings. According to Taliaferro (in Louderback 18), one large lens of high-grade ore mined during World War I had a maximum length of 90 feet and a thickness that pinched and swelled from 1 foot to 12 feet.

Production figures for this area are incomplete. The Rustless Mining Corporation produced 16,130 tons of ore averaging 9 percent of Cr_2O_3 and removed 72,250 tons of waste from pit 5. Using the ratio of these figures and the volume of the pit as a basis, it is calculated that the total amount of ore produced from the pit was approximately 17,600 tons. The 718 tons of ore of similar grade produced from pit 5A necessitated the removal of 32,000 tons of waste; the large ratio of waste to ore can be attributed to the initial development of a pit planned to be much larger than actually was dug. Taliaferro reported the Noble Electric Steel Company shipped "fully 2,500 tons of 46 to 47 percent ore" from the underground workings during World War I. The U. S. Chrome

Mines, Inc. shipped 217 long tons of ore averaging 43 percent of Cr_2O_3 and the Rustless Mining Corporation produced 913 tons of milling-grade ore from these workings. All or part of the 162 long tons of shipping-grade ore that J. J. Taylor produced from the Pillikin mine in 1945 may have come from the underground workings in this area.

Area 3, West Basin. Area 3, also known as West Basin, is in the SE¼SW¼ sec. 21 and the NE¼NW¼ sec. 28. Since it was described by Wells, et al., in Bulletin 922-0, nine additional pits and numerous bulldozer cuts have been made, the old pits have been enlarged, and the old underground workings have been extended (see pl. 15). The area has been restudied and mapped in detail (see pl. 10). Because the additional development work has made more detailed geologic study possible, the observations and interpretations that follow differ somewhat from those in Bulletin 922-O.

Relatively unsheared dunite is the predominant rock type in the area, although small bodies of pyroxenite and lherzolite are enclosed by, or project into, the dunite. Silicified rocks border the dunite on the east, south, west, and a part of the north margins of the area. Although the dunite is almost completely serpentinized and commonly silicified, only a minor amount of alteration to talc, so prevalent in other areas, is present here. Some of the silicified and deeply weathered dunite in Shovel Pit No. 7 is slightly nickeliferous.

Two systems of schistose metadiorite dikes, now extensively altered to talc and chlorite, are injected along faults that cut West Basin. One dike system trends N. 30°-45° W. over most of the area, and the other, confined mostly to the northeastern part of the area, trends N. 60°-70° E. These dikes appear to have been altered hydrothermally, and all gradations from apparently unaltered, hard, fine-grained diorite to schistose talc-chlorite rocks exist. The relationship of the two dike systems is not entirely clear, for nowhere were they observed to cut one another; however, because of similarity in composition and alteration, they are believed to be approximately contemporaneous.

In some places the fractures followed by the dikes also appear to have been the channels of silica-bearing solutions. Many of the minor fissures in the area are filled with magnesite and yellow serpentine and, more rarely, with opal. Few of the magnesite veins are more than an inch or two thick, but three laminated veins 2 to 4 feet thick crop out along the north wall of pit 3.

Scattered over the surface of West Basin are 13 ore bodies sufficiently large for power-shovel mining, and many smaller ones. Despite the random distribution, there is a general orientation of elongate bodies and lenses and layers of chromite parallel to the west contact of the ultramafic and metamorphic rocks. Many ore layers and lenses are folded locally and are cut by numerous small faults that in many places disturb the strike and dip of the layering. The major departures from the general trend of the layering, such as occur in pits 3 and 17, probably are attributable to flowage and folding before complete solidification of the cooling ultramafic mass. Ore layers in pit 3 form an anticlinal fold pitching northwest.

The chromite occurs as layers, disseminated grains, nodules, and lenticular masses in a matrix of dunite. Disseminated ore containing 10 to

20 percent of chromite makes up the bulk of the ore bodies. The individual chromite grains range from 0.2 millimeter to 2.0 millimeters in diameter throughout most of the disseminated ore. A small amount of nodular ore, consisting of nodules of chromite about 7 millimeters across, was mined in pit 7, but none can be seen now except on the dumps. Lenses of massive ore are common in pits 2 and 3, and have been mined from the underground workings as shipping-grade ore. Most of these lenses are less than 6 inches thick, but some attain a maximum thickness of 4 feet.

The limits of the ore bodies generally are indefinite because the percentage of chromite decreases gradually outward, and because many bodies are sheared and brecciated. Barren dunite is found in many places within the limits of the ore bodies. A few ore bodies are faulted off, the most prominent example being that cut by the fault on the south rim of pit 3.

The composition of the concentrates made from the ores of West Basin varied, and considerable magnetic material generally was present. Such material was especially abundant in concentrates made from the ore mined in pit 12, one carload of which contained more iron than chromium. As is true of ores from elsewhere on the Pillikin property, concentrates made from ores in area 3 containing fine-grained chromite were low in chromic oxide and high in iron.

As a rule, ore occurring in silicified areas cannot be milled profitably unless the rock is highly brecciated and deeply weathered, as in pits 7 and 16. The amount of grinding necessary to free the chromite from the silicified matrix causes excessive sliming and a consequent lowering of recovery.

It has been calculated that approximately 125,000 tons of ore and waste have been removed from the surface workings, plus an undetermined tonnage from the underground workings. According to the records of the Rustless Mining Corporation, 5,937 tons of ore and 13,077 tons of waste were removed from the various pits within the area during 1941 and 1942. Except for pit 3, from which 2,435 tons of ore and only 472 tons of waste were taken, the ratio of waste to ore is about 3.6 to 1. Application of this ratio to the total tonnage of material excavated indicates that a total of about 27,000 tons of ore has been mined from the surface workings in West Basin.

Accurate determinations of reserves are impossible as practically all the ore bodies have only one face partly exposed. Consequently, the tonnage of measured ore is small. A total of 142,000 tons of material estimated to contain more than 8 percent of chromite is indicated by surface exposures, underground workings, and reasonable downward projections of exposures. About half of this material contains 12 percent or more of chromite and the rest between 8 and 12 percent. The chromite content of an ore is not a true measure of its grade, but an ore containing 12 percent of chromite ordinarily carries at least 5 percent Cr_2O_3, the cutoff grade generally used at the Pillikin property when the mill was in operation.

Because of the random distribution of the ore bodies, no generalizations or criteria can be stated to guide the search for ore bodies not yet exposed. If the need for high-cost ore justified a drilling program directed at discovering new ore bodies, about 600 holes centered not more than 50 feet apart and drilled to depths of 200 feet would be required to avoid missing ore bodies large enough to be mined. An alternative program would be the exploration of known ore bodies to greater depths, and of the known ore bodies only those in pits 2, 3, and 7 would seem to offer any reasonable promise. Subsurface exploration to a depth of at least 100 feet below the underground workings on the ore body in pit 2 would be of greatest value because this is the largest ore body in the area and contains the largest amount of shipping-grade ore. This ore body has a length of about 500 feet and may extend down the dip a comparable distance.

Area 4, Chrome Gulch. Area 4, in the bottom of Chrome Gulch in the SW¼ sec. 21, was described briefly by Wells, et al., in 1940. At that time the area had been prospected by a number of scattered pits. After the U. S. Chrome Mines, Inc. resumed operations at the Pillikin mine in September 1942, the area was exposed further by a large bulldozer scrape and a number of bulldozer cuts, which were mapped in detail by G. A. Rynearson, F. W. Cater, Jr., and D. H. Dow late in December 1942 and early in January 1943 (see pl. 11).

The country rock is largely unsheared, partly serpentinized dunite. Several small masses of pyroxenite and layered olivine and pyroxene rocks are enclosed by the dunite, and a large mass of similar rocks crops out southwest of the area. The contact between the ultramafic and metamorphic rocks is immediately northwest of the area mapped. Numerous small dikes of schistose metadiorite and partly altered diorite occur along fissures in the dunite. Except for a small mass of talcose rock in the northwest part of the area, the alteration to talc, magnesite, and silica-rock, characteristic of many parts of the Pillikin mine, is practically absent.

Scattered throughout the dunite are numerous large and small, schlierenlike zones relatively rich in chromite. Two major ore bodies and several smaller ones are partly exposed. The chromite occurs as disseminated grains and thin layers of disseminated grains in a matrix of dunite; a few thin lenses of nearly solid chromite occur also.

Layering of the chromite is unusually prominent in many places. The layers in the western ore body strike N. 5°-45° E. and dip 45°-75° NW., and those in the eastern ore body strike N. 20° E. to N. 10° W. and vary in dip from 55° W. to 80° E. Layers of chromite near the edges and ends of the ore zones are contorted in many places, and a small anticlinal fold in thin chromite layers was observed at one place in the bottom of the gulch. The edges and ends of the ore zones have a shredded appearance because of the uneven lengths of the different groups of chromite layers.

Although no systematic sampling has been done in the area, the writers believe that the ore bodies shown on the map (pl. 11) average at least 5 percent Cr_2O_3. One sample of massive ore contained 44.1 percent of Cr_2O_3, and a cleaned concentrate of the same sample contained 54.07 percent of Cr_2O_3 and 14.13 percent of Fe. The concentrate from a chip sample across the eastern ore body was strongly magnetic and that from a chip sample across the western ore body contained a strongly magnetic fraction; both were high in iron. Table concentrates of the ore possibly can be beneficiated by some process of magnetic separation.

Indicated reserves of the western ore body, calculated from an exposed length of 400 feet, an indicated maximum depth of 140 feet, and an average width of 90 feet, are 250,000 tons of ore. It is possible that the ore extends beneath the surface southward along the strike for about 100 feet to the large pyroxenite mass, if so, additional reserves of ore are approximately 30,000 tons.

Indicated reserves of the eastern ore body, calculated from an exposed length of 210 feet, a maximum exposed depth of 75 feet, and an average thickness of 65 feet, are 45,000 tons of ore. If the ore extends 25 feet deeper, the reserves are increased by about 15,000 tons.

The total indicated reserves of ore in the larger ore bodies is about 340,000 tons, and it may be possible to obtain approximately 2,000 tons of additional ore from some of the smaller ore bodies. Although low in grade, the disseminated ore bodies in Chrome Gulch appear to contain the largest reserve of chromite, albeit high in iron, of any group in the Flagstaff Hill area, or perhaps in the entire state.

Area 5, Placer Chrome Co. Workings (26). Area 5 is about three-quarters of a mile north of area 2 in the western part of the NE¼ sec. 21. A number of glory holes, shafts, and pits are scattered for a distance of about 1,000 feet along the flanks and crest of a northerly trending ridge. The underground workings are inaccessible. The Placer Chrome Company shipped 7,270 long tons of lump ore and concentrates in 1917-20, but no mining has been done since 1920.

Wells (40) described the geologic setting of the area as follows:

> "The chromiferous dunite interfingers with chlorite, epidote, and hornblende schists and amphibole contact rocks to the northwest. Thin bands of these schists, as well as schistose and massive dioritic dikes, usually less than 5 feet thick, are common in the dunite but occupy less than 1 percent of the entire area. The dunite is in fault contact with hornblende and chlorite schists on the west. Eastward it grades through lherzolite into a small pyroxenite mass. Shearing is prominent only near the edges of the area, where silicified shear zones truncate the chromiferous dunite on the north and south."

The ore is similar to that occurring at the Pillikin mine. The disseminated ore is characterized by a more even distribution of the chromite than is common elsewhere in the Flagstaff Hill area, but alternating layers of high- and low-grade ore, schlieren, and clots do occur. Old workings indicate that a zone of higher-grade ore trended north along the crest of the ridge, and smaller high-grade zones are indicated by scattered prospect pits. Over half the ore mined by the Placer Chrome Company is said to have been lump ore from lenses and pods of massive and nearly massive chromite. Nothing definite is known concerning the reserves, but careful exploration might reveal considerable quantities of milling ore.

Area 6. Area 6 includes those deposits in the mass of dunite in the north central part of the SE¼ sec. 28 on the property of the Steele Estate. The Steele Chrome Company prospected the area with several trenches, pits, and short adits during World War I. In 1918 brush was cleared for a tramway to the mill site in sec. 33 but the tram was not erected and it is doubtful if any of the ore ever was concentrated. Subsequent to Wells' investigation in 1939, a small amount of prospecting with a bulldozer indicated the ore zone to be discontinuous and not as extensive as was thought formerly. The following statements summarize Wells' report on the area.

The dunite mass is bordered by lherzolite on the north and by pyroxenite on the east, south, and west. The adjacent lherzolite is massive and unsheared but is cut by numerous dikes, which extend into the dunite. Bodies of disseminated ore containing a few high-grade streaks are scattered through a zone about 100 feet wide and 800 feet long, but most of these ore bodies are too small for profitable power-shovel mining. The ore lenses strike N. 10° W. and dip 70° E.

A statement of reserves is little better than a guess; exposures indicate at least 10,000 tons of ore containing 5 percent or more of Cr_2O_3 and possibly larger reserves could be found by more thorough prospecting.

Area 7. Area 7 extends north-northwestward from Steel Estate property in the NE¼NE¼ sec. 28 to join with the northward extension of area 2 on Pillikin property in the SE¼ sec. 21. A small but indeterminate amount of ore has been mined from this locality since 1940 and some prospecting has been done. The following description is taken largely from Wells.

The workings consist of scattered pits and trenches. These expose relatively small masses of disseminated ore in a talcose dunite body about 200 feet wide and at least 1,500 feet long. The principal ore zone, one in the northeast corner of the NW¼NE¼ sec. 28, trends N. 35° W. and is separated from the pyroxenite to the west by 20 feet of talc rock that contains only a little disseminated chromite. Reserves are difficult to estimate, but perhaps 25,000 tons of material containing 5 percent or more of Cr_2O_3 remain in the known ore zones.

Area 8. Area 8 lies near the schist-dunite contact in the SE¼NW¼ sec. 21, about halfway between Chrome Gulch and the Placer Chrome Company workings, on the Zantgraf gold mine property. No work has been done in the area since 1940. The following description is quoted from Wells (40):

> "Six pits and short adits, now caved, have opened up high-grade layers (40 percent Cr_2O_3), as much as 24 inches thick, which have a general trend of N. 25° E. The enclosing dunite contains from 2 to 4 percent of disseminated chromite. This area is probably part of a larger zone that is more or less continuous along the trend of the main dunite body.
>
> "Included stringers of metamorphic rocks, intrusive diorite dikes as much as 50 feet thick, and silicified rocks make up a considerable portion of the area, and it is improbable therefore that mining could be carried on in the area without hand picking. By this method 500 tons or so of ore containing 40 percent of Cr_2O_3 might be produced under favorable conditions."

Area 9, Nielson or Donnelly Mine (24). Area 9 is in the SE¼ sec. 21. The workings in this area constitute what was known during World War I as the Nielson or Donnelly mine. Federal records indicate that 224 long tons of ore was shipped from the mine in 1916-17 but whether this was the entire production is unknown. Some bulldozer trenching has been done in the area since 1940 but apparently no ore was mined. The dunite country rock has been almost completely altered to talc although it lies between relatively fresh lherzolite to the west and silicified lherzolite to the east. Most of the ore mined occurred as irregular lenses of nearly pure chromite up to 18 inches thick, but associated with this ore was some disseminated chromite. Many diorite dikes cut across the ore layers and would interfere with mining. The area seems unlikely ever to be very productive.

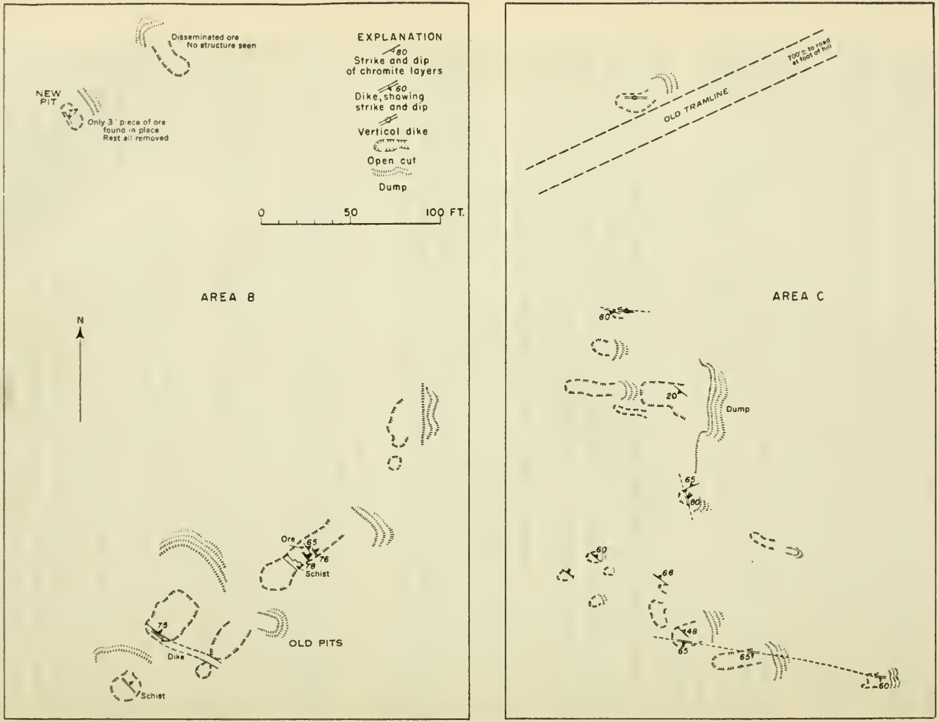


FIGURE 4. Sketch maps of workings in areas B and C, Dobbas mine, El Dorado County, California.

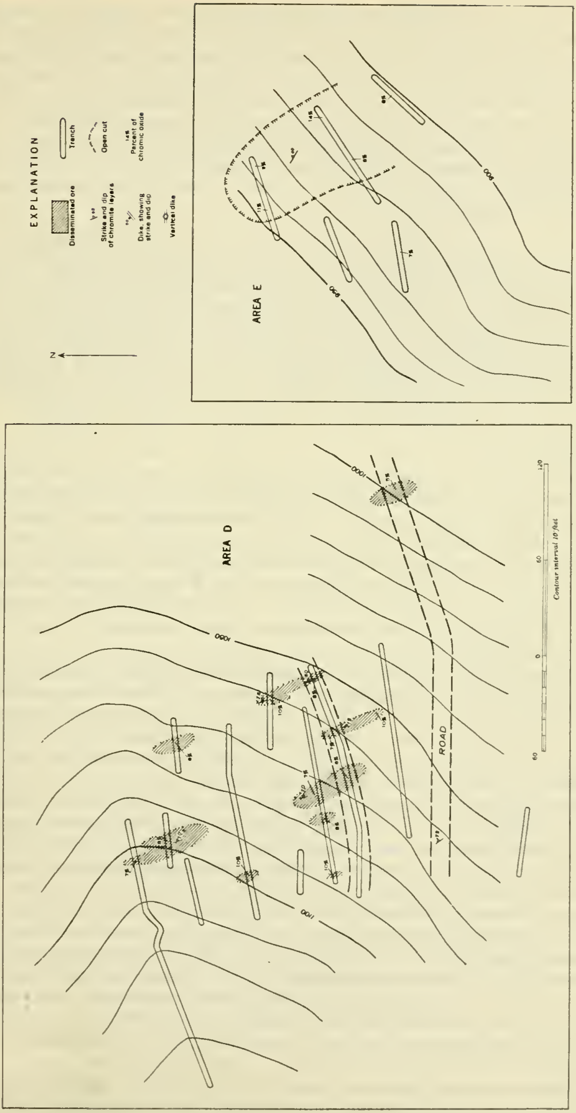


FIGURE 5. Sketch maps of workings in areas D and E, Dobbas mine, El Dorado County, California.

Area 10. Area 10 is in the southeast corner of the NW¼ sec. 28. The dunite in which the ore deposits occur is about 1,000 feet long and has an average width of 250 feet but tapers out to the south. This mass probably was continuous with the mass in West Basin, but the two parts now are separated by a zone of silicified rocks about 500 feet wide. A few small pits near the schist-dunite contact expose disseminated ore containing some high-grade streaks that strike N. 25° W. and dip 75° E., parallel to the contact. Although the workings reveal some fairly good ore, the grade of most of it apparently was too low and the ore bodies too small for profitable mining.

Area 11. Area 11 lies between areas 1 and 2 in the NW¼NE¼ sec. 28 and may represent a part of one ore zone extending through all three areas. It is described separately because of the high degree of silicification and strong shearing. Several lenses of high-grade ore, some of which were nearly 3 feet thick, have been mined from shallow pits, inclined shafts, and adits that have since caved. The strikes of the lenses range from N. 60° E. to N. 60° W. None of the lenses could be followed far. Because of the discontinuity of the ore streaks and the difficulty of milling the siliceous ore, no large production from this area seems probable.

Dobbas Mine (25)

The Dobbas property consists of about 900 acres in the W½ sec. 15, the E½ sec. 16, and the NW¼, N½SW¼, SE¼SW¼ sec. 22, T. 11 N., R. 8 E., about 10 miles south of Auburn. D. J. Dobbas of Auburn is the owner and J. J. Taylor is lessee. Most of the chromite deposits on the property occur on the east slope of the ridge underlain by the Flagstaff Hill ultramafic mass (see pl. 9). These deposits fall into five main groups or areas, which have been designated as areas A to E in this report (see figs. 4 and 5). Part of area C may be in the extreme northeast corner of the Pillikin property.

The property was the site of considerable activity during World War I. At one time during this period the Placer Chrome Company owned or leased all of the lands covered by the present property and subleased a part of its holdings, that part known as the Holmes Chrome mine, to the Union Chrome Company in 1918. The Wells lease described by Cameron (18) appears to have been a part of this property also. The old workings consisted of several large pits, numerous small pits, and several shafts and adits. Many of the smaller pits are nearly obliterated and the underground workings are inaccessible. In 1941 the Rustless Mining Corporation obtained an option on the property and prospected areas D and E with trenches and bulldozer cuts. In December 1941 the Marsman Company, under the sublease from Taylor, stripped some ore from area D and concentrated it along with ores from other deposits at the Volo mill near Placerville. The carload of concentrate produced from these ores was high in iron and was rejected by the Metals Reserve Company. Taylor opened up one small pit in area B and a number of small pits in area C, and shipped about 20 long tons of the ore in 1942 and a small but unspecified quantity combined with some ore from the Darrington mine in 1944.

The country rock in areas A and B and a part of area C is an injection complex of ultramafic and metamorphic rocks composed mostly of metamorphic rocks but including many small injected masses of ultramafic rock. Much of the ultramafic rock is hardly recognizable as such, being highly altered to talc-chlorite or talc-serpentine rock; however, most of the ultramafic material in this part of the property, as well as in areas D and E, appears to have been dunite originally. Silicified rocks and magnesite are subordinate.

A heavy mantle of soil covers most of the east slope of the ridge, outcrops are scarce, and although ore occurs in many of the outcrops of ultramafic rock these occurrences undoubtedly represent scattered ore bodies rather than more or less continuous ore zones. Most of the ore bodies apparently trend north to northwest, roughly parallel to the eastern margin of the ultramafic mass. Many of these are from 700 to 1,000 feet west of the contact, but several are within 200 feet of the contact. All the ore bodies opened so far have been small; many contained only a few tons of low-grade ore. Little massive ore has been exposed; however, some ore bodies contain layers rich in disseminated chromite that attain a thickness of 12 inches or more in some places. Assays of ore from several of the pits indicate that the ore contains a high percentage of iron. Some of the ore is magnetic enough to attract a compass needle held an inch or two away.

Area A includes three open cuts, one, and perhaps two, of which are collar shafts, and an adit driven in the general direction of the shafts from a point eastward and down the slope. The underground workings are inaccessible and little can be seen in the cuts. One wall of the lower cut, which is near the contact, exposes a zone of hybrid rock including altered metamorphic rocks and dunite and a dike of diorite. A small streak of ore can be seen in this wall and about a ton of ''high-grade'' disseminated ore is piled on the dump. Apparently the shaft was sunk on a lens or zone of such ore.

Area B includes six old pits and one new pit (see fig. 4). The old pits seem to be prospect holes as ore can be found in only one. A small lens of high-grade or nearly massive ore, assaying 24.61 percent of Cr_2O_3 and 24.4 percent of Fe, was mined from the new pit. The ore still remaining in the new pit strikes N. 30° W. and dips steeply eastward. One large diorite dike is exposed by two of the pits.

Area C has been prospected by numerous small pits and trenches. Some of these workings are shown in the sketch on figure 4. Several other similar openings are located northwest of the old tramway and not far below the crest of the ridge, and a few others are located eastward down the slope. At least four pits have been dug not far west of the contact. In the group of pits sketched, there appear to be two low-grade ore bodies occurring en echelon in an ore zone that trends north-northwestward. The chromite is coarse-grained and occurs as thin layers and schlieren. The layers strike about N. 45° W.; those in the northern part of the zone dip southwest whereas those in the southern part dip northeast. Analyses indicate that the ore contains from 13 to 30 percent of Cr_2O_3. The zone is traversed by vertical faults that strike nearly east.

The ore in area D is exposed by a number of trenches (see fig. 5), and consists of disseminated chromite in sharply bounded layers 1 inch to 3 inches thick, which strike N. 20° W. and dip 75° E. Closely spaced groups of layers comprise many small discrete ore bodies. Analyses made by the Rustless Mining Corporation indicate the ore averages 6 to 8 percent of Cr_2O_3.

The workings in area E consist of an open cut and a number of exploratory trenches (see fig. 5). The ore in this area is similar to that in area C and strikes N. 60° W. and dips 60° N. Analyses indicate the ore contains 6 to 8 percent of Cr_2O_3.

In view of the large number but limited size of the ore bodies and the small amount of exploration work done on the Dobbas property, no attempt has been made to estimate reserves. Furthermore, all assays indicate the ore is high in iron and, although the ore is of high enough grade for milling purposes, the concentrates would be of undesirable quality.

Bases for the maps of areas D and E were furnished by the Rustless Mining Corporation. Assays were furnished by J. J. Taylor and the Rustless Mining Corporation.

Hoosier Gulch Placers, Granite Bar (27)

Considerable quantities of chromite-bearing sand and gravel are known to occur on the North Fork of the American River at Granite Bar in the SE¼ sec. 20, T. 11 N., R. 8 E., about 1 mile by road from the site of the Pillikin mill. A dragline dredge owned by Hoosier Gulch Placers was working the gravels of Granite Bar and adjacent Long Bar until closed down by the war on December 1, 1942. Inasmuch as Granite Bar is at the mouth of Chrome Gulch which heads in the chromite-bearing serpentine of the Pillikin and adjacent chrome mines, the occurrence of chromite in the gravels of the bar is to be expected.

The major part of Granite Bar is on the south side of Chrome Gulch; drilling indicates this part of the bar has an average depth of 19 feet. It is notable that the drill logs note ''heavy chrome sands'' only in the upper part of the holes. This does not necessarily mean that chromite-bearing sands do not occur at depth or that all of the black sand near the surface is chromite. It does indicate, however, that the deeper gravels consist largely of material brought down the river and that the relative abundance of chromite near the surface is due to a lesser degree of transfer and reworking of chromite-bearing material washed onto the bar from Chrome Gulch.

On the north side of Chrome Gulch a low rise is covered with gravel. Several drill holes and some dragline trenches on the ravine side of the rise indicate an average depth of 6 feet for the gravel. If the rise is a topographic expression of a low ridge of bedrock, the gravel is probably shallow throughout this area. It appears that this part of the bar contains more chromite than the part south of the gulch. Large lumps and coarse gravel of chromite were encountered frequently during the dredging operations.

The only reliable information available regarding the black sand content of the gravel was obtained from a 400 pound sample of bank-run gravel from near the surface south of the gulch which yielded 15 pounds of concentrate. The concentrate contained 24.9 percent of Cr_2O_3 and 39.5 percent of Fe. A nonmagnetic fraction representing 17 percent of the concentrate contained 45.2 percent of Cr_2O_3 and 23.0 percent of Fe.

Probably 180,000 cubic yards of gravel remained to be worked when the dredge closed down.

Steele Mine (22)

The Steele mine includes those deposits in the NE¼ sec. 33 and the NW¼NW¼ sec. 34, T. 11 N., R. 8 E. Those deposits in area 6 and part of area 7 in the N½SE¼ and the NE¼NE¼ sec. 28 also are on the Steele property but are described under the Pillikin mine. The Steele Estate is the owner. The Placer Chrome Company owned and worked the deposits first during the early part of World War I, but in 1918 the Steele Chrome Company acquired the property and built a mill in the NW¼NW¼ sec. 34. The mill was dismantled when the price of chromite dropped at the end of the war. Later, during the period 1940-42, the Rustless Mining Corporation bulldozed a trail to the upper workings in sec. 34 and did some prospecting with the bulldozer but mined no ore. Some bulldozer prospecting also was done at the deposit in sec. 33.

The deposits were worked by a number of open cuts, prospect pits, and adits, but all the adits have caved and some of the cuts have been filled or partly destroyed by later bulldozer work. Placer Chrome Company shipped 12 cars of chromite, mostly concentrates, from this and other properties, but what amount came from the Steele mine is not known. The Steele Chrome Co. shipped 313 long tons of chromite from the deposits.

Little can be seen now in the large cut on the deposit near the west contact in the NE¼ sec. 33 except that the chromite occurred in serpentinized dunite cut by many seams of magnesite and opal. According to Allen (41), an adit 150 feet long was driven on a low-grade ore zone trending N. 20° W. which could be traced for 150 feet south of the adit portal. The open cut has obliterated the old workings. Taliaferro (in Louderback 18) indicated that bands or lenses of high-grade ore up to 3 feet thick occurred in the low-grade ore.

The upper workings in sec. 34, at the end of the bulldozer trail on the east slope of Flagstaff Hill, were made on ore bodies occurring in a body of dunite about 100 feet wide and several hundred feet long. The serpentine surrounding the dunite appears to have been derived largely from lherzolite. Both the lherzolite and dunite have a marked schistosity, but this schistosity is not so well developed in the dunite. Numerous schistose chloritic dikes, veinlets of hard, nonflexible fibrous serpentine, and some veins of magnesite cut the rocks in the area. As is common at the Pillikin mine, some of the rock has been silicified.

Several types of ore are present in the upper deposits. Most common is a layered ore made up of alternating layers of high-grade, in places almost pure chromite, and low-grade disseminated chromite. These layers strike N. 50°—60° W. and dip steeply eastward. Less common is an ore composed of oriented pencil- and torpedo-shaped aggregates of chromite grains. In a few places the inverse of nodular ore has been formed; this ore consists of nodules of barren dunite as large as 15 millimeters in diameter contained in a matrix of evenly disseminated ore. Almost invariably the leaner ores are made up of smaller chromite grains than the richer ores. Some of the small crystals in the leaner ores may be magnetite; the chromite in at least some of the nearly massive ore is notably magnetic. A little bleached kammererite may be associated with the high-grade ore, but no uvarovite was seen. Much of the ore has been cut by numerous dikelets of barren dunite, and some of the thick layers of nearly pure chromite show considerable magmatic brecciation. The dikelets of dunite and the magmatic brecciation are presumed to have occurred during a late stage of the magmatic processes.

The lower workings in sec. 34 are along or near the contact between the ultramafic and metamorphic rocks, and consist of four adits and three small open cuts. The adits are inaccessible, but seem to be the same as the ones described by Taliaferro (in Louderback 18). When Taliaferro visited the property in August 1918 the northernmost adit had been driven 185 feet N. 63° E. without encountering ore, the next adit south was 125 feet long and had 9 feet of low-grade ore at the face, and the other two adits exposed from 3 to 6 feet of ore containing from 12 to 17 percent of Cr_2O_3. When Rynearson examined the workings in 1949 some banded and disseminated ore could be seen in two irregular cuts above the second adit, and several zones of disseminated ore from 1 foot to 2 feet wide were exposed in another cut just south of the southernmost tunnel. The ore in the last cut had a strike of N. 10° E. and a dip of 75° E. A sorted dump near this same cut contains about 20 tons of low-grade ore, and about 10 tons of similar ore is piled at the old mill site. The strike of the exposed ore and the alignment of the workings both are roughly parallel to the contact and suggest the existence of one ore zone about 500 feet long; however, if such a zone exists, it is not likely that the ore is continuous throughout the length of the zone.

On the basis of what can be seen in the open cut, no reserves can be estimated for the deposit in the NE¼ sec. 33. Reserves of the ore bodies in the NW¼NW¼ sec. 34 cannot be estimated with any accuracy until additional development work is done and a detailed geologic map is made. Though ore is exposed at numerous places, individual ore bodies rarely are traceable for any distance and commonly end abruptly. Few, if any, of the bodies now exposed are of sufficient size to mine by power-shovel methods, and unless further development work and geologic mapping show that these bodies are numerous enough and spaced closely enough to permit the mining of large blocks of ground by low-cost, large-scale methods, it is questionable whether the reserves of economic ore are very large. Economic or not, a small amount of shipping-grade ore could be selectively mined, and a few thousand tons of milling-grade ore could be extracted. On the whole, most of the ore probably contains less than 10 percent Cr_2O_3.

Darrington Mine (21)

The Darrington mine is in the SE¼ sec. 33, T. 11 N., R 8 E., about 10.5 miles by road northeast of Folsom. Mrs. Jane Darrington is the owner. The history and past production of the property are uncertain; apparently several different operators, among them F. Gurney, Holbrook & McGuire, and possibly the Steele Chrome Company, worked the mine during World War I. Several hundred tons of ore is reputed to have been produced during this period. J. J. Taylor operated the property in conjunction with the Dobbas mine during World War II, and shipped a total of 495 long tons of ore, most of which came from the Darrington deposits.

A number of open cuts and trenches, 4 adits having a combined length of 900 feet, and more than 120 feet of shafts and raises comprise the workings; in addition the eastern ore body has been explored by four diamond-drill holes.

The chromite occurs in two major ore zones, each in separate masses of dunite, which are separated by a mass of pyroxenite. The eastern dunite mass is bounded by pyroxenite on the east, and the western mass is bounded by the contact with metamorphic rocks on the west. The west ore zone is smallest and has been worked less extensively. It lies almost along the contact with the metamorphic rocks, and has been exploited by numerous small pits, trenches, and shallow shafts. The ore zone appears to be discontinuous and broken by many small faults, and may be cut off at the north end by shearing along the contact. The ore is of the low-grade disseminated type, but some layers and lenses of ore rich enough to be sorted out as shipping-grade ore occur in the low-grade ore.

The east ore zone is approximately 300 feet long and has a maximum thickness of 70 feet; the thickness in the lowest adit is about 15 feet. The difference in elevation between the ore exposed in the upper open cut and that in the lowest adit is about 300 feet, and the continuity of the ore zone down the dip is indicated by one diamond-drill hole drilled from the upper cut which is alleged to have been in ore for 180 feet of its 200 feet of length. The ore consists of both evenly disseminated chromite and thin alternating rich and lean layers of disseminated chromite in a matrix of serpentinized dunite. Three samples of the ore, selected as being ''typical'' of the ore in the zone, were assayed and found to contain 11.34, 13.76, and 16.65 percent of Cr_2O_3.

On the basis of the ore exposed at the surface and in the underground workings in 1943, it is estimated that a total of about 100,000 tons of indicated milling-grade ore may remain in the east ore zone. The ore in the west ore zone is too poorly exposed to permit a valid estimate of reserves to be made, nevertheless, one can assume that further work might lead to the development of at least several thousand tons of milling-grade ore in this zone.

Despite the relatively large reserves of milling-grade ore indicated for the deposits at this mine, future exploitation is shadowed somewhat by the high iron content of the ores. Three small lots, aggregating about 62 long tons, of sorted ore mined from the west ore zone during 1942-44 averaged 38.5 percent of Cr_2O_3 and 16.3 percent of Fe with a Cr to Fe ratio of 1.61. Two small batches of ore from the east ore zone were test-concentrated by the Dorr Company for the Kaiser Company in 1942. The heads contained 10.83 and 13.52 percent of Cr_2O_3 and the composite concentrate contained 45.15 percent of Cr_2O_3 and 20.66 percent of Fe with a Cr to Fe ratio of 1.49. Magnetic separation did not improve the grade of this concentrate materially. Therefore, although the grade of the reserves should average between 10 and 15 percent of Cr_2O_3, it appears that any concentrates made from the ore will be undesirable because of high iron content.

Burnett Property (20)

The Burnett property, or Burnett Ranch, includes those deposits in the NE¼ sec. 3, T. 10 N., R. 8 E., and those along the western edge of sec. 34, T. 11 N., R. 8 E., south of the Steele workings. The Noble Electric Steel Company leased the property during World War I and mined and shipped some lump ore. This company also erected a small concentrating plant on the property and may have concentrated some of the disseminated ore from the deposits in sec. 3. Only a little prospecting has been done since World War I. A production of 139 long tons of ore is recorded.

The most promising deposit found so far on the property is located in the bottom of a wide gulley close to the western margin of the ultramafic mass and about 700 feet south of the north edge of sec. 3. In this place a dozen or more small open cuts, pits, and shallow shafts have been made in layered and disseminated ore containing about 20 percent of Cr_2O_3. The strike of the layering in the ore varies widely from place to place; most layers strike at a large angle to the contact. The scattering of the workings and the discordance of the structures in the ore may indicate the ore body has been broken and jumbled by many small faults. With a little more systematic prospecting it should be possible to determine the extent of the ore body with some certainty, but no reliable estimate of reserves can be made at this time. Most of the low-grade shipping-ore produced by the Noble Electric Steel Company from the Burnett property probably was sorted from the ore in this deposit.

Several prospect holes have been dug on scattered deposits of very low grade disseminated ore along an old road at the south end of the Flagstaff Hill ridge (just south of the area shown on Pl. 9). Only two of these prospects were visited, and neither appeared to offer much promise.

The deposits in sec. 34 are similar in most respects to those in the Steele workings to the north. The northernmost of the Burnett deposits is only about 500 feet south of the southernmost Steele deposit. An open cut and a drift about 50 feet long have exposed a narrow zone of low-grade disseminated ore containing a few higher-grade lenses. The zone strikes N. 20° W. and is nearly vertical. About 15 feet west of the open cut a similar zone of ore is exposed by small prospect pits. About 5 tons of ore containing 30 or 35 percent of Cr_2O_3 is scattered on the dumps. In the gulley southeast of these workings several narrow zones of disseminated chromite occur in dunite at the contact with the metamorphic rocks. About 100 feet south of the gulley two trenches have been dug across a zone of medium-grade layered and disseminated ore from 5 to 10 feet wide. This ore strikes N. 35° W. and dips 75° E. Located 200 feet to the south is an open cut 5 to 8 feet wide and 25 feet long that exposes another lens of disseminated ore. The dump of this cut probably contains 5 or 10 tons of ore containing 20 or 25 percent of Cr_2O_3. Across a gulley and about 100 feet southwest of the latter cut are two cuts 5 to 15 feet across, one of which exposes a zone of low-grade disseminated ore striking N. 10° W. and dipping 85° E. It may be that these prospects all lie along one ore zone, but the ore appears to be discontinuous and the individual ore bodies all appear to be small and low in average grade.

Another deposit, located in the southwest corner of sec. 34, has been opened by an irregular open cut and an inclined shaft. The ore consists of a heavy dissemination of chromite in dunite, and may contain 35 or 40 percent of Cr_2O_3. It occurs as irregular lenses from 6 to 12 inches thick along a vertical fault or plane of schistosity that strikes N. 37° W. The shaft and cut follow this plane for about 40 feet along the strike to a depth of about 40 feet, where the ore seems to pinch out. This deposit seems to warrant no further exploration.

Miscellaneous Deposits

About a dozen small prospect pits have been dug on chromite in the long, narrow dunite body at the north end of the ultramafic mass in the northeast corner of sec. 16 and the southeast corner of sec. 9. Those in sec. 16 probably are on Dobbas property, but the ownership of those in sec. 9 could not be ascertained. A little high-grade layered and disseminated ore can be seen in some of the prospects, but it appears that very little ore remains in any of them. The layers strike almost parallel to the contact and dip steeply east or are almost vertical; a few are contorted into small folds. Little is known about the history or production of these deposits except that small amounts of ore has been shipped from some of them, probably during World War I.

Webber Creek Area

The Webber Creek area lies in the low hills about 7 miles west of Placerville. All the chromite deposits in this area are contained in a single serpentine mass of highly irregular outline. The form of the serpentine mass appears to be that of a complexly folded sill, and much of the irregularity of outline probably is nothing more than the surface expression of this folding. The sill intrudes rocks of the Amador group, and is cut off on the north by a large mass of granodiorite.

None of the chromite properties in this area have been worked since 1918 and most of them appear to be worked out.

W. W. Irish Property (28)

P. A. Smith shipped 18 long tons of chromite from property owned by W. W. Irish in sec. 20, T. 10 N., R. 10 E. Workings consist of a number of small pits and caved shafts; the deepest of the shafts is reputed to have been 25 feet deep. A number of small pods and stringers of medium-grained, massive chromite were mined from sheared serpentine. No ore remains in sight.

Thomas and Meldrum Lease (29)

Some old workings just north of Dry Creek in sec. 18, T. 10 N., R. 10 E. appear to be the same as those described by Cameron (18) as the Thomas and Meldrum lease. Thin stringers and small kidneys of rather fine-grained chromite were mined from two shafts. The shafts are filled to about 20 feet below their collars. The surrounding serpentine is sheared. About a carload of ore is reputed to have been shipped from this mine, although no report of such production appears in Federal records.

Gordon Property (30)

George A. Gordon shipped 31 long tons of chromite in 1918 from his property in sec. 13, T. 10 N., R. 9 E. All this ore consisted of float derived from a mass of almost pure chromite eroded from nearby; the only ore found in place consisted of a small lens of very low-grade disseminated chromite.

Hector Williamson Property

The mine on the Hector Williamson property is 5 miles southwest of Coloma in sec. 7, T. 10 N., R. 10 E. The mine was not visited by personnel of the Geological Survey. The following description is quoted from Taliaferro (in Louderback 18):

> "A few yards off the road is a 20-foot shaft, with a short tunnel leading off from the bottom. No ore was seen in place. The small amount found having been entirely mined out. The serpentine occasionally contains a few scattered grains of chromite. From the irregularity of the workings it seems probable that the ore occurred in small irregular masses in the serpentine.
>
> "There are several other small deposits on this property, none of which have yielded more than 3 or 4 tons. Altogether about 40 tons of ore have been shipped."

Williamson Mine (31)

The Williamson mine is half a mile east of the bridge over Webber Creek and just south of the creek in the N½ sec. 7, T. 10 N., R. 10 E. The workings are caved. The chromite apparently occurred as irregular pods in slickentite. Scattered specimens of ore from the dump are of brecciated medium-grained chromite containing small amounts of interstitial serpentine and talc. According to Taliaferro (in Louderback 18), 55 long tons of ore containing about 40 percent of Cr_2O_3 was mined from the deposit and no ore remained in the mine.

McDonald and Buys Mine (32)

The McDonald and Buys mine is in sec. 6, T. 10 N., R. 10 E., about three-quarters of a mile from Webber Creek. The mine was owned by the McDonald brothers and Archie Buys, and they are reported to have shipped about 350 long tons of chromite from the mine during World War I. The mine has not been seen by the present writers and the following description is based on Cameron's (18) brief report. The workings comprised a group of three shafts 16 to 42 feet deep, a number of stopes, and one pit. The ore consisted of coarse-grained, massive chromite occurring as irregular pods in sheared serpentine. The zone of pods trended north and dipped nearly vertically.

The mine was closed down and flooded at the time Cameron made his report, but the report gives the impression that ore still remained in the workings.

Wiley Mine (33)

D. E. Wiley shipped 45 long tons of chromite in 1916 from a deposit in sec. 1, T. 10 N., R. 9 E. Nothing else is known about the deposit.

Pilot Hill Area

Only one chromite deposit is known in the Pilot Hill area. This deposit is 2 miles southwest of the village of Pilot Hill in an area of low, rolling hills. The mass containing the deposit consists of relatively fresh peridotite intruded into sedimentary and volcanic rocks of the Amador group. Considerable gabbro crops out along the east margin of the peridotite. A number of small serpentine masses crop out between Pilot Hill and Greenwood but in only one has a chromite deposit been found (see under Garden Valley area).

Pilot Hill Mine (34)

The Pilot Hill mine is a few hundred feet west of the summit of Pilot Hill in sec. 12, T. 11 N., R. 8 E. The workings consist of an open cut about 65 feet long, 5 to 20 feet wide, and 10 feet deep at the face, and a caved drift driven from near the center of the cut. The country rock is slightly serpentinized saxonite in which are scattered a few lenses of dunite, one of which contains the chromite deposit. Some of the olivine crystals in the dunite show conspicuous cleavage surfaces. A strong system of rather widely spaced joints striking N. 35° E. and dipping 30° SE. cut the peridotite. Prominent also, especially in the dunite, is a vertical sheeting structure or pseudo-schistosity striking N. 55° W.

The ore body is lenticular, elongated in a northeasterly direction and dipping steeply southward. It consists of a mass of pods, clots, and layers of high-grade ore and small amounts of disseminated ore. The chromite grains are small; few are more than 1 millimeter in diameter. Veins of serpentine, opal, and magnesite cut the ore and peridotite.

According to Logan (in Bradley 18), the Union Chrome Company operated the mine in 1916 and shipped about 200 long tons of the ore. Apparently the mine has been idle since 1916. Only a few tons of low-grade ore remains in the mine and on the dumps.

Garden Valley Area

The chromite deposits of the Garden Valley area lie 2 to 4 miles northwest, west, and southwest of Garden Valley. That part of the area bordering the South Fork of the American River is steep and rough, but the rest of the area is rolling and the relief is low. All but one of the chromite deposits occur in a single serpentine mass that is cut off on the south by granodiorite. Although the serpentine near Garden Valley cuts across the enclosing rocks of the Carboniferous Calaveras formation and appears to be dikelike in form, this mass and the serpentine of the Webber Creek area may have been parts of one large mass before the intrusion of the granodiorite.

Only one property in the area has been mined and one or two others prospected since the end of World War I. Most of the deposits appear to be mined out and only one appears to have appreciable reserves.

McCurdy Mine (35)

The McCurdy mine is about 3 miles southwest of Garden Valley in the NW¼ sec. 8, T. 11 N., R. 10 E. G. O. Fisher operated the property during World War I, but no ore has been mined since 1918, although trails have been bulldozed to some of the workings and a small amount of exploration work has been accomplished in recent years. The principal workings are in two groups, the north group and the south group, and in addition to these a number of small pits and open cuts are scattered about in the brush nearby.

The north deposit was worked from an open cut about 60 feet long, 10 to 15 feet wide, and 6 to 10 feet deep, and from a shaft in the south end of the open cut. The shaft is caved but is reputed to have been 45 feet deep. Several small vertical lenses of chromite that trended N. 30° E. were mined from the open cut. According to Taliaferro (in Louderback 18), a lens of chromite 4 feet wide and 14 feet long was exposed in the shaft in 1918, but whether this ore was mined before the shaft caved is not known. The ore consisted of medium-grained chromite with considerable interstitial serpentine and talc. The ore, and the serpentine country rock as well, is highly sheared, and contacts between the ore and serpentine are slickensided.

On the crest of the ridge several hundred feet south of the open cut is a flooded shaft around which is scattered some evenly disseminated, medium-grained chromite. The serpentine matrix of the ore and the surrounding serpentine is soft, highly altered, and intensely sheared.

The other deposits were smaller and each yielded only a few hundred pounds to 10 tons of ore.

According to Taliaferro, about 100 long tons of ore containing 31 to 36 percent of Cr_2O_3 had been shipped from the property by August 1918, and, in addition, 100 long tons of ore was sorted and piled ready for shipment. Inasmuch as this pile of ore is no longer present it is presumed that this ore was shipped also. Thus the total production probably was in the neighborhood of 200 long tons, but no accurate record of the production exists. Reserves probably are small.

O'Brien Mine (S-Bend Mine) (36)

The O'Brien mine is 2 miles north of Coloma on a steep, southeast-facing hillside just west of Perry Creek in sec. 6, T. 11 N., R. 10 E. The mine was worked from two adits, a glory hole, and a shallow inclined winze near the face of the lower adit (see fig. 6). The upper adit which tapped the glory hole had caved, but the lower adit still was accessible when the property was visited by Cater. The stopes in the lower adit are in a precarious state, and no attempt was made to enter them. Several hundred tons of ore was mined from the property in 1918, and in 1942 about 3,000 tons was mined by the Volo Mining Company and concentrated at its mill near Shingle Springs.

The ore body consists of a lens of mixed disseminated and nearly massive chromite contained in a body of relatively unsheared dunite that is surrounded by saxonite and pyroxenite. The only ore in sight consists of a few scabs plastered on a fault surface that forms the footwall of the ore along the east face of the glory hole, and along the last 20 feet at the rear of the lower adit. In the lower workings the ore body dips very steeply southwest. Most of the contacts of the ore and wall rock are sheared and slickensided, but locally the contacts are gradational. The dimensions of the stopes indicate that the ore body had a maximum width of about 20 feet. The chromite grains are from 0.5 millimeter to 3 millimeters in diameter, and some of the ore has a spotted appearance that seems to have resulted from the breaking up of nodular ore when the rock was still in a plastic state.

Little ore remains above the level of the lower adit, but perhaps 25 tons of ore remains for each foot below that level that the ore body maintains the same horizontal dimensions.

Maxwell Mine (37)

According to Cameron (18), Grover Maxwell operated a mine in sec. 6, T. 11 N., R. 10 E., about 3 miles from Lotus; the mine is not mentioned in other reports and Cater was unable to find the old workings. Maxwell is reported to have shipped 687 long tons of chromite in 1916-17, but, although Cameron reported that ore was being shipped in 1918, there is no record of how much ore was shipped in 1918. Cameron's description of the workings is too brief to indicate whether or not 687 long tons of ore could have been mined from the property. Cameron's report indicates that an adit followed a series of chromite stringers and pods into the hill. The reserves, if any, are not known.

Simon Mine (38)

The Simon mine is about 2¼ miles southwest of Garden Valley and consists of two groups of deposits in the NE¼SE¼ sec. 5, T. 11 N., R. 10 E. During World War I the property was leased and operated by G. Simon, but the mine has been idle since that time.

The north workings are on the south slope of a gentle ridge and comprise two open cuts; the upper cut trends N. 10° E., is 60 feet long, 10 feet wide, and 10 feet deep, and the lower cut trends N. 23° E., is 60 feet long, 3 to 4 feet wide, and 6 feet deep. The ore occurs in a lens of dunite

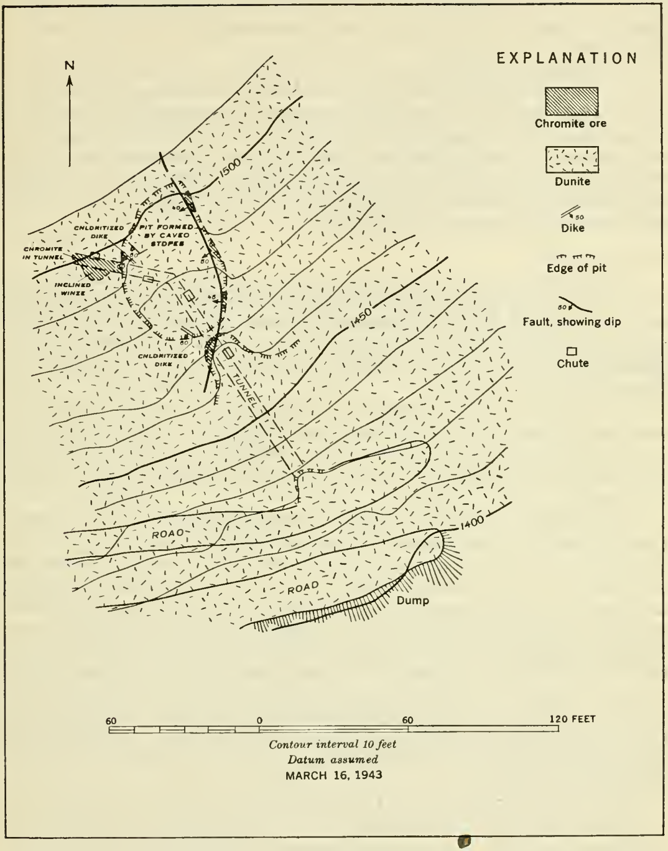


FIGURE 6. Sketch map of the O'Brien mine, El Dorado County, California.

surrounded by saxonite. Both rocks are thoroughly serpentinized and are traversed by numerous serpentine veinlets. Most of the ore consists of medium-grained, nearly pure chromite, but some specimens of layered ore from the dump contain about 30 percent of interstitial serpentine. Two lenses of chromite 6 inches thick are exposed in the west wall of the upper cut. Contacts of the chromite and serpentine are sheared, and the north end of the deposit is cut off by a vertical, northeast-trending fault. Considerable chromite float is scattered over the ground north of the workings.

The south workings are about 800 feet south of the north workings on the north slope of a low ridge. Ore was mined from a pit 20 feet long, 15 feet wide, and 10 feet deep. A few small stringers of medium-grained, massive chromite and some low-grade disseminated ore remain in the walls of the pit.

According to Taliaferro (in Louderback 18), two or three carloads of ore containing 34 to 36 percent of Cr_2O_3 was shipped from these deposits, but Federal records list a production of only 94 long tons and of this amount 45 long tons were sold in 1920 two years after Taliaferro's visit. About 11 tons of ore left over from the operations done during World War I is piled at the foot of the ridge between the two deposits. Known reserves are very small, though the abundant float may indicate the presence of undiscovered deposits.

Shelly Mine (39)

The Shelly mine, also known as the Wolf mine, is a quarter of a mile north of the Simon mine near the crest of a low ridge in the SW¼NE¼ sec. 5, T. 11 N., R. 10 E. The property was held by Andrew Wolf in 1945, but was owned formerly by Mrs. L. M. Shelly and was operated during World War I by the Union Chrome Company. The mine has been idle since 1918.

The visible workings consist of an elliptical pit 60 feet long and 35 feet wide. According to Taliaferro (in Louderback 18), in 1918 the pit was 30 feet deep with a 15-foot shaft in the bottom. A short drift is said to have run southward from the shaft. All but the upper 6 feet of the pit are flooded.

The chromite occurs as a number of irregular lenslike masses oriented along a north-trending zone in sheared serpentinized dunite. The dunite forms a lens in the predominantly saxonitic country rock. The ore zone, especially, is highly sheared and some of the chromite masses appear to be blocks sheared off larger chromite bodies. Both the plane of shearing and the ore bodies dip about 70° W. Chromite is exposed intermittently for about 170 feet along the strike of the zone, but the ore bodies that have not been mined are very small. Although some of the ore is nearly pure chromite, most of it contains considerable interstitial serpentine and talc. Of the secondary chrome minerals, only kammererite is present. Most of the chromite grains are from 1 millimeter to 3 millimeters in diameter, but a few pieces of ore from the dump contain nodules of chromite as much as 7 millimeters across.

The recorded production of the mine totals 1,284 long tons of ore that contained about 30 percent of Cr_2O_3. A few tons of unmined ore is in sight in the walls of the pit and in scattered outcrops, and 5 or 6 tons of ore remains on the various dumps.

Veerkemp Mine (40)

The Veerkemp mine, named after the owner, is in sec. 33, T. 12 N., R. 10 E., on the south slope of a low hill a few hundred feet north of the Garden Valley-Lotus road about 1½ miles southwest of Garden Valley. Workings comprise a group of five small pits and open cuts, the largest of which is 20 feet long and 5 feet deep. These are scattered over an area about 150 feet square.

A number of small pods of high-grade massive chromite and of medium-grade evenly disseminated chromite were taken from the pits and open cuts. The pods had strikes of about N. 35° W. and dipped steeply eastward. The surrounding serpentine is highly sheared, and the contacts between the chromite and serpentine were slickensided. In places, some of the disseminated ore has been ground to an intimately mixed chocolate-colored mass of chromite and serpentine. There are no Government records of the production from this property, but Taliaferro (in Louderback 18) reported that 38 long tons of ore containing 41 percent of Cr_2O_3 was shipped in 1916. Only a few pounds of ore remain in place in any of the workings, but 2 or 3 tons of ore remain on the dumps.

Nearly half a mile west of the deposits described above, just above the road, is a caved shaft about 15 feet deep in highly sheared serpentine. A few pieces of nearly massive chromite are scattered about the dump, but no other ore is in sight. Nothing is known about the production from this deposit.

Laicey Claim (41)

The Laicey claim is about 1¾ miles due west of Garden Valley in sec. 32, T. 12 N., R. 10 E. At least a dozen small pits, shafts, and open cuts are scattered over an area about a quarter of a mile long on the east slope of a low ridge, and all the workings are within a few hundred feet of the east contact of the serpentine. The serpentine enclosing the various chromite pods is highly sheared and in places is partly altered to talc. The chromite pods are small, and most of them probably contain less than 5 tons of ore. Ore from the various pods differs considerably in texture and grade; some pods are composed of almost pure, massive chromite, and others are of evenly disseminated chromite in which the matrix makes up as much as 40 percent of the material. No production records for this property exist, but a small amount of chromite appears to have been mined. Reserves are very small.

Sheppard Mine (42)

The Sheppard mine is on the crest of a low ridge in sec. 32, T. 12 N., R. 10 E., about 2 miles west-northwest of Garden Valley. During World War I the deposits were mined by the Union Chrome Company. The mine has been idle since 1918.

The north deposit was worked from an open cut that trends N. 35° W. and is 25 feet long, 5 to 6 feet wide, and 6 feet deep. The ore body consisted of a lens of chromite containing considerable interstitial serpentine. Both the ore and the enclosing serpentine wall rock is highly sheared, and some of the chromite has been comminuted to an extremely fine-grained, chocolate-colored mass having a dull luster. A small amount of ore remaining in the ends of the cut dips 50° E.

About 300 feet south of the north deposit are two caved shafts approximately 15 feet apart, one of which is at least 30 feet deep. Taliaferro (in Louderback 18) reported that a number of short drifts extended both northward and southward from the deeper shaft, and that a number of small lenses of ore were mined from these workings. A lens of chromite 3 feet thick, striking N. 30° E. and dipping 60° SE., is exposed between the two shafts. Most of the ore apparently consisted of almost massive chromite, but there is also some highly sheared disseminated ore in small lenses and along the margins of the remaining massive ore. The surrounding serpentine is highly sheared, and contacts between the chromite pods and the serpentine are slickensided.

Although no production from this property is recorded officially, Taliaferro reported that 50 long tons of ore containing 34 or 35 percent of Cr_2O_3 had been shipped by the 1st of August 1918, and at that time ore was being mined at the rate of about 50 long tons per month. A few tons of ore remains in place in the deposits.

Central Pacific Railroad Land (43)

Chromite deposits were mined first by the Union Chrome Company and later by C. C. Gaylord and J. B. Landis on land belonging to the Central Pacific Railroad Co. in 1916-18. These deposits were in the E½ sec. 23, T. 12 N., R. 9 E. about 2 miles southwest of Greenwood. The deposits were not visited by personnel of the Geological Survey, and the following description is summarized from Taliaferro's report of 1918 (in Louderback 18).

Ore was mined from an open cut 45 feet long, 30 feet wide, and 5 to 8 feet deep, and from a shaft 17 feet deep in the bottom of the open cut. An irregular, lenslike mass of chromite trending N. 15° W. and dipping 70° E. was mined from these workings. The remaining ore, where exposed in the bottom of the shaft, was 1 foot to 2 feet wide. The surrounding peridotite is hard and relatively unsheared although partly serpentinized. Much of the ore was nearly pure chromite containing little interstitial silicate material, but some consisted of disseminated grains and isolated clots of chromite scattered through the serpentine. The ore is alleged to have contained from 35 to 41 percent of Cr_2O_3 depending on the care with which it was sorted. From 200 to 250 long tons of ore was shipped in 1916 and 1917, and although 40 additional long tons had been mined at the time of Taliaferro's visit near the end of August 1918, the production for 1918 is unknown. Unless ore produced from this mine is included in the production figures listed under ''others'' table 1, the shipments from this mine are not included in Federal records. Taliaferro indicated that the chances of discovering other ore bodies were favorable.

Georgetown-Volcanoville Area

The chromite deposits of the mountainous Georgetown-Volcanoville area occur in a complex dikelike mass of ultramafic and gabbroic rocks that lies about a mile east of Georgetown and extends northward through Volcanoville and beyond. The southern part of this mass, 2 miles to 4 miles south-southeast of Georgetown, intrudes the Jurassic Amador group, but northward the mass is confined largely to the Carboniferous Calaveras formation.

Considerable ore was shipped from the area during World War I, and 316 long tons of lump chromite was shipped from mines active during World War II.

Stifle Prospects (44)

The Stifle prospects are on land owned by W. L. Stifle in sec. 25, T. 12 N., R. 10 E., about 1 mile south of the Black Oak mine (45). A number of shallow pits and trenches are scattered about the property on both sides of Traverse Creek. No ore is visible in any of the workings, but specimens from the dumps are of medium-grained massive chromite. All the pods mined were very small. The serpentine is highly sheared, and in places it contains considerable talc. A few tons of ore is said to have been mined in 1917-18, but aside from a small amount of prospecting, no work has been done since. Although other pods of ore probably exist, the small sizes of those already discovered would indicate that any pods discovered in the future are likely to be small also.

Black Oak Mine (45)

The Black Oak mine, also known as the Cassiorni mine, is 2 miles south of Georgetown on a low ridge a few hundred feet west of Traverse Creek in the E½NE¼ sec. 23, T. 12 N., R. 10 E. It is reported that 36 long tons of ore was shipped from this mine during World War I, and 107 long tons of ore containing 47.50 percent of Cr_2O_3 and 11.49 percent of Fe was delivered to the Auburn stockpile during 1942-43. The property is owned by the Southern Pacific Lands Company and was operated last by Russel Wilson. The workings comprise a group of three shafts about 40 feet deep, an open cut, and a number of small trenches. The ore consists of rather coarse-grained, massive chromite occurring as pods and irregular lenses in slickentite. In general, the lenses strike N. 20°-30° E. and dip 60°-70° SE. None of the pods mined were large, the largest containing perhaps 50 long tons of ore. Small amounts of uvarovite and kammererite are present in the ore. Reserves, though indeterminate, undoubtedly are small.

Green Claim (46)

The Green claim is northeast of the Black Oak mine (45) and is on the east side of and about 100 feet above Traverse Creek in the NW¼ sec. 24, T. 12 N., R. 10 E. W. C. Green located the claim and leased it to the L. H. Butcher Co. during World War I, but the property has been idle since 1918. Workings consist of a shaft about 15 feet deep and a caved drift extending from the bottom of the shaft. The chromite occurs as pods that trend northwestward parallel to the plane of shearing in highly sheared serpentine. The chromite is coarse-grained and black and contains very little interstitial serpentine. Accurate production data are unavailable, but Taliaferro (in Louderback 18) reported that about 17 long tons of ore had been mined prior to his inspection of the claim in August 1918. The ore is said to have assayed 51 percent of Cr_2O_3. A few pounds of chromite is visible in the sides of the shaft.

Henser Mine (47)

W. A. Henser mined 13 long tons of chromite in 1918 from a deposit in sec. 14, T. 12 N., R. 10 E. Nothing else is known about this deposit.

Stafford Mines (48)

The Stafford mines are about 2 miles northeast of Georgetown in sec. 36, T. 13 N., R. 10 E. A number of small open cuts, pits and trenches are scattered along the west side of a spur ridge of the Hornblende Mountains. Most of these were opened during World War I, but a small amount of ore was mined by George Knoff in 1942 and 1943 and sold with the ore mined from the Knoff mines (49). According to Taliaferro (in Louderback 18), the largest cut was 17 feet deep and in the bottom of it was an eastward trending incline; these working are caved now. The ore consists of massive, medium-grained chromite occurring as small, irregular pods and lenses that strike north and dip 40°-50° E. Considerable kammererite is associated with the chromite. The enclosing serpentine is highly sheared, and the contacts of the ore bodies and serpentine are slickensided. Some chromite float has been dug from the soil downhill from the open cuts.

Federal records indicate that 198 long tons of chromite was shipped from the property in 1918, and Knoff shipped a few tons in 1942 and 1943. Reserves are small.

Knoff Mines (49)

The Knoff mines, also known as the Austin, the Bald Mountains, and the Federwitz mines, are 3 miles northeast of Georgetown along the crest and east side of a southward trending spur ridge of the Hornblende Mountains in sec. 25, T. 13 N., R. 10 E. The road from the mines to the highway at Georgetown is steep and rough, and during wet weather it is impassable. Ore has been mined from more than a dozen pits, open cuts, and shafts, and from numerous placer operations in the overlying soil mantle.

The ore in place generally occurs as rather small pods and lenses of high-grade massive chromite, although small amounts of disseminated ore is found also. Most of the ore bodies strike N. 20°-30° W., but one small body of layered disseminated ore strikes N. 55° W. Grains of chromite in the ore range from 1 millimeter to 3 millimeters in diameter except where the ore is brecciated and sheared. The brecciated ore is very fine-grained, has a chocolate-brown color, and a dull luster. Associated with the chromite are small amounts of uvarovite and kammererite. The serpentine country rock is highly sheared, and in places it has a peculiar, bright green color. Although the contacts of the chromite and serpentine are sheared and slickensided, the chromite does not always break cleanly from the serpentine.

Considerable float ore was mined during World War I by plowing the ground and picking out the chromite pebbles and boulders, and most of the mining activity during 1942-44 also was directed at recovering the float ore by sluicing methods. Water was pumped up the hill from a ditch heading farther up the gulch, and the soil was shovelled into sluice boxes from which the chromite pebbles were collected later. Such operations are of necessity limited to the wet season when water is available.

Taliaferro (in Louderback 18) reported that nearly 400 long tons of chromite was shipped from the deposits in 1917 and 1918. From 1942 to 1944 about 79 long tons of chromite was shipped to the stockpiles of the Metals Reserve Company.

Chrome Divide Group (50)

The Chrome Divide group consists of two claims that were operated from 1941 to 1943 by R. N. Knudsen. Both claims are in the NE¼SW¼ sec. 25, T. 13 N., R. 10 E., about 3 miles northeast of Georgetown. The ore is similar to that of the other mines in the area, and consists of medium-grained massive chromite occurring as small pods and lenses. These pods and lenses strike about N. 25° W. and dip steeply eastward. The surrounding serpentine is highly sheared, and contacts of the ore bodies and serpentine are slickensided. A total of 51 long tons of chromite has been shipped from the deposits. Deeper mining may find other pods, but in any event the reserves are small.

Green Mine (51)

The Green mine, also known as the Ruby mine, is about 1½ miles south-southwest of Volcanoville near the bottom and on the north side of the canyon of Otter Creek in sec. 19, T. 13 N., R. 11 E. The property consists of a group of claims belonging to the Green Estate. These were leased to and operated by the L. H. Butcher Co. during World War I and John J. Taylor in 1942. The mine was operated originally for gold, and chromite was discovered during the progress of development work. Workings comprise about 350 feet of adit, two short crosscuts, a 60-foot raise, a winze 20 feet deep, and, on the surface 180 feet above the adit level, a caved shaft about 40 feet deep.

The adit crosses the contact between serpentine and black slates about 300 feet from the portal. The serpentine is highly sheared near the contact, which is essentially parallel to the schistosity of the slate. Chromite was discovered in the serpentine about 30 feet from the contact, and was mined from the winze and raise. Inasmuch as neither the winze nor the raise are accessible, no ore can be seen in place, but the chromite lens is reputed to have had a maximum thickness of 7 feet and to have extended along most of the length of both the winze and raise. Small veins of calcite, talc, and kammererite are very numerous in specimens of ore from the dump and in the serpentine. The ore consists of medium-grained, massive chromite, much of which is highly brecciated and slickensided. Taliaferro (in Louderback 18) reported that 110 long tons of chromite was shipped from the property in 1917 and an unknown quantity in 1918. In 1942 Taylor shipped 64 long tons of the ore. Possibly other ore bodies exist between the shaft and the top of the raise underground, but reserves probably are small.

Apex Claim (52)

The Apex claim is three-quarters of a mile southwest of Volcanoville in the SW¼ sec. 18, T. 13 N., R. 11 E. In 1918 the claim was worked by J. A. Shields, but was abandoned later. The following description is based on Taliaferro's report (in Louderback 18).

Small eastward trending pods of massive chromite were mined from a pit 15 feet deep. The ore is said to have been cut by a number of vertical faults. The serpentine is highly sheared. About 8 long tons of ore had been mined but none was visible in the workings at the time of Taliaferro's visit.

Hill-Top Chrome Mine (53)

The Hill-Top Chrome mine is in the SW¼ sec. 18, T. 13 N., R. 11 E., about 400 feet north of the Apex claim. The mine was worked by M. C. Langstaff and G. E. Bromm in 1918, but since then it has been idle. The following description is summarized from Taliaferro's report of 1918 (in Louderback 18).

The workings comprised a shaft, vertical to a depth of 10 feet and said to have been inclined at an angle of 60°-65° W. for an additional 12 feet. The ore is said to have occurred as patches of chromite caught in the slips of the sheared serpentine. No ore was visible at the time of Taliaferro's visit. The serpentine ranges from a soft, light-colored, weathered material at the surface to a hard, grayish-green rock near the bottom of the shaft. About 7 long tons of ore had been mined by August 1918, and the deposit apparently had been worked out.

Ogle Mine (54)

The Ogle mine is 1 mile south of Volcanoville at an elevation of 3,100 feet in sec. 18, T. 13 N., R. 11 E. The following description is quoted from Logan (in Bradley 18):

Table 5. Alphabetical list of chromite mines and prospects in El Dorado County, California

Map No.	Property	Owner	Location			Class by production*	Remarks
			Section	T. (N)	R. (E)		
52	Apex	J. A. Shields	SW¼ 18	13	11	C	Worked out
	Austin: See Knoff mines						
	Bald Mountain: See Knoff mines						
45	Black Oak	Southern Pacific Lands Co.	E½NE¼ 23	12	10	C	
	Bonanza King: See Pillikin, area 2						
9	Bonetti	C. and A. Bonetti	N½ 7	8	10	D	
8	Brandon	G. and M. Brandon	SE¼ 12	8	9	C	Worked out
6	Bryant	------	SE¼ 13	8	9	C	
20	Burnett	F. L. and D. W. Burnett	NE¼ 3	10	8	------	
			W½ 34	11	8	B	Disseminated ore
	Cassiorni: See Black Oak						
43	Central Pacific Railroad	------	E½ 23	12	9	B	
11	Chaix	R. H. Chaix	NE¼ 14	8	9	B	
50	Chrome Divide	R. N. Knudsen, operator	NE¼SW¼ 25	13	10	C	
15	Cowell	Cowell Lime and Cement Co.	4 (?)	9	9	B	Location uncertain
21	Darrington	Jane Darrington	SE¼ 33	11	8	B	Disseminated ore
14	Dickson	Dickson	SW¼ 4	9	9	C	Mined out
25	Dobbas	D. J. Dobbas	W½ 15	11	8	------	
			E½ 16	11	8	------	
			W½ 22	11	8	B	Disseminated ore
24	Donnelly: See Pillikin, area 9	------	NE¼SE¼ 21	11	8	------	
	Ehler and Hoff: See Gold Bug						
13	Ever	Ever	32	9	9	D	
	Federwitz: See Knoff mines						
	Forni	J. C. Forni	------	------	------	C	Location uncertain
5	Freeman	E. L. Freeman	SE¼ 24	8	9	C	
4	Gold Bug	R. H. Chaix and George Gardner	SW¼ 19	8	10	C	
30	Gordon	George A. Gordon	13	10	9	C	
27	Granite Bar	Hoosier Gulch Placers, Inc.	SE¼ 20	11	8	D	Chromite in gravel
46	Green claim	W. C. Green	NW¼ 24	12	10	C	
51	Green mine	Green Estate	SW¼ 19	13	11	B	
3	Helemar: See also Trio Chrome Co. leases	Robert Haddock and R. H. Chaix	NW¼ 30	8	10	C	
47	Henser	W. A. Henser	14	12	10	C	
53	Hill-Top Chrome	M. C. Langstaff and G. E. Bromm	SW¼ 18	13	11	C	Worked out
1	Hoff: See also Trio Chrome Co. leases	Robert Haddock and R. H. Chaix	W½ 30	8	10	B	
	Holmes: See Dobbas						
	Hoosier Gulch Placers: See Granite Bar						
28	Irish	W. W. Irish	20	10	10	C	

16	Joerger	J. G. Joerger	SW¼ 35	10	8	B	Disseminated ore
49	Knoff mines	George B. Knoff	25	13	10	B	
41	Laicey	Sam Laicey	E½ 32	12	10	C	
37	Maxwell	Grover Maxwell	6	11	10	B	
35	McCurdy	E. P .McCurdy	NW¼ 8	11	10	B	
32	McDonald and Buys	McDonald Bros. and A. Buys	6	10	10	B	Shipped about 350 long tons
18	Miller	F. E. Walker	NW¼ 35	10	8	C	
	Mundrini	Michail Mundrini				C	Location uncertain
10	Murphy	P. B. Murphy	SE¼ 14	8	9	B	Disseminated ore
24	Nielson: See Pillikin, area 9		NE¼SE¼ 21	11	8		
36	O'Brien	J. O'Brien	SE¼ 6	11	10	B	Considerable low grade ore remains
			NE¼ 7	11	10		
54	Ogle	E. C. and W. M. Ogle	SE¼ 18	13	11	C	
7	Pfeiffer	Wm. Pfeiffer	7	8	10	C	Worked out
23	Pillikin, areas 1-11	Pillikin Syndicate, C. P. Carruthers, Trustee	21	11	8	A	Shipped 27,144 long tons including concentrates
24			28				
26			29				
34	Pilot Hill	John Revoir and Frank Costa	12	11	8	B	
26	Placer Chrome Co. workings: See also Pillikin, area 5		NE¼ 21	11	8	A	Shipped 7,270 long tons including concentrates
2	Placer Ground: See also Trio Chrome Co. leases	Robert Haddock and R. H. Chaix	NE¼ 25	8	9	D	Chromite in gravels
	Ruby Consolidated: See Green mine						
	S-Bend: See O'Brien						
39	Shelly	Andrew Wolf	SW¼NE¼ 5	11	10	A	Shipped 1,284 long tons
42	Sheppard	D. L. Sheppard	N½ 32	12	10	C	
38	Simon		NE¼SE¼ 5	11	10	C	
19	Simpson		13	10	8	C	
12	Smith	Ray, George, and Ellen Smith	NW¼ 9	8	9	B	
48	Stafford	Mrs. M. N. Stafford	N½ 36	13	10	B	Disseminated ore
22	Steele: See also Pillikin, areas 6 and 7	Steele Estate	E½E½ 28	11	8		
			NE¼ 33	11	8		
			NW¼NW¼ 34	11	8	B	Mostly disseminated ore
44	Stifle	W. L. Stifle	N½ 25	12	10	C	
29	Thomas and Meldrum lease	Royce	SE¼ 18	10	10	C	
1-3	Trio Chrome Co. leases	Robert Haddock and R. H. Chaix	24 and 25	8	9	D	
			19 and 30	8	10	B	
40	Veerkemp	F. L. Veerkemp	SW¼ 33	12	10	C	Mined out
17	Walker	F. E. Walker	SW¼ 35	10	8	B	Mostly disseminated ore
33	Wiley	D. E. Wiley	1	10	9	C	
31	Williamson mine	Southern Pacific Lands Co.	N½ 7	10	10	C	Worked out
	Williamson, Hector	Hector Williamson	7	10	10	C	
	Wolf: See Shelly						
	Zantgraf: See also Pillikin, area 8	H. B. Drescher and Louise Kleinsorge	SE¼NW¼ 21	11	8	C	

* A, 1,000 tons or more; B, 150-1,000 tons; C, some, but less than 150 tons; D, no ore shipped.

"It [the mine] is owned by E. C. and W. H. Ogle of Volcanoville, and was worked in May, 1917, by the Union Chrome Company of San Francisco, whose lease has since expired.

"Chrome lenses striking north-south in serpentine had been open cut to a depth of approximately 20′, irregularly, for a distance of 75′. About 47 tons of 45% ore were shipped from [to?] Auburn, a distance of 36 miles."

ALPHABETICAL LIST OF MINES AND PROSPECTS

In the accompanying table the chromite mines and prospects in El Dorado County are listed alphabetically. The ownership, where known, is given as of the date of the last report on the property. The deposits are divided by production into four classes: A, deposits or properties that have shipped at least 1,000 long tons; B, deposits that have shipped between 150 and 1,000 long tons; C, deposits from which small amounts of ore, but less than 150 long tons, have been shipped; and D, deposits from which no ore has been shipped.

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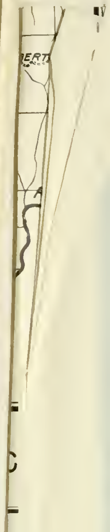
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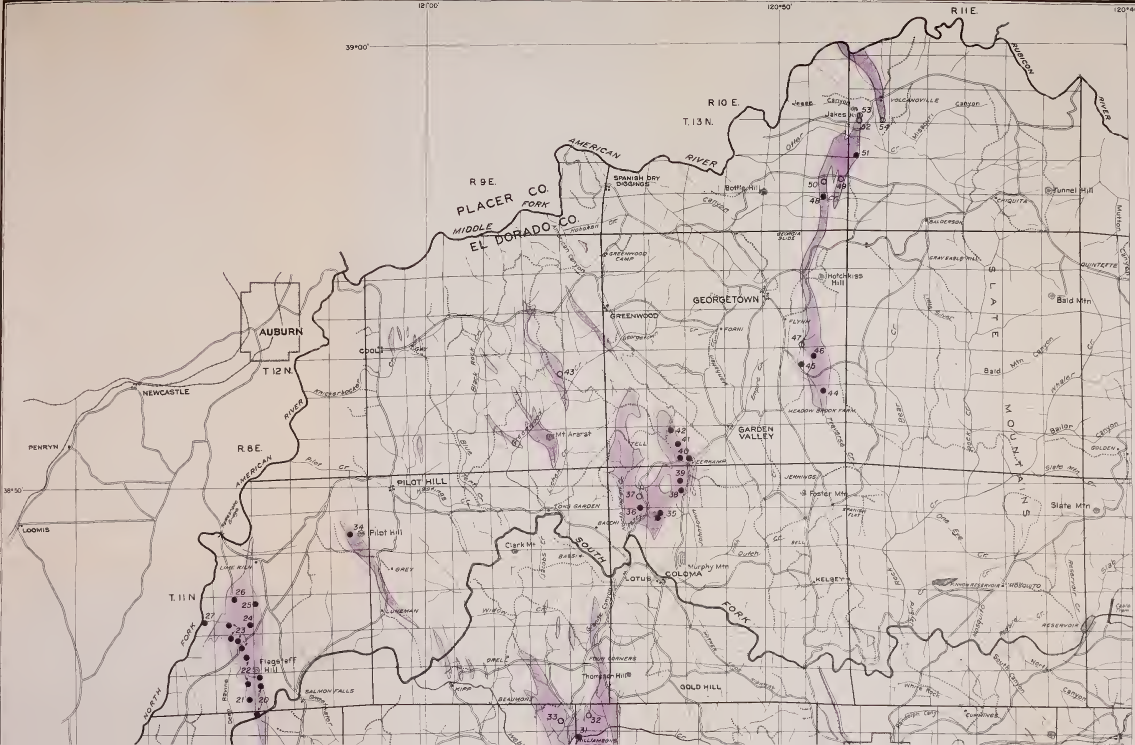


EXPLANATION

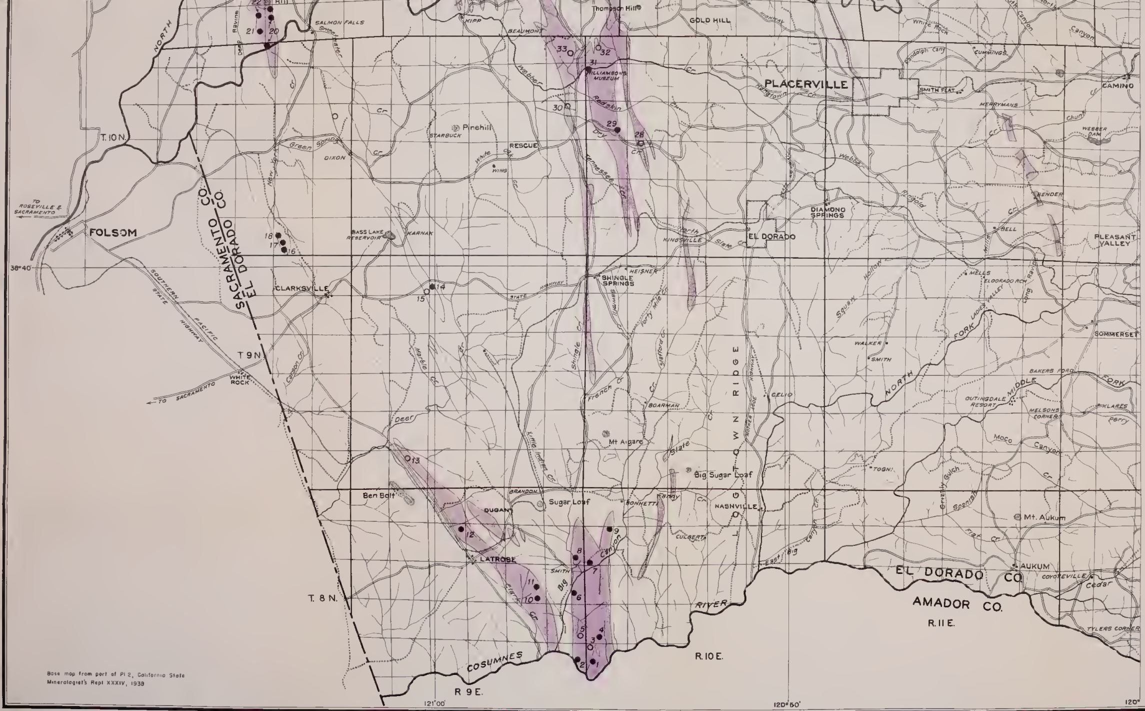
▨ Serpentine

● Mines accurately located

○ Mines approximately located

LIST OF MINES AND PROSPECTS

NAME	NO
APEX	52
BLACK OAK	45
BONETTI	9
BRANDON	8
BRYANT	6
BURNETT	20
CENTRAL PACIFIC RAILROAD	43
CHAIX	11
CHROME DIVIDE	50
COWELL	5
DARRINGTON	21
DICKSON	14
DOBBAS	25
EVER	2
FREEMAN	5
GOLD BUG	4
GORDON	30
GRANITE BAR	27
GREEN CLAIM	46
GREEN MINE	5
HELEMAR	3
HENSER	47
HILL-TOP CHROME	53
HOFF	1
IRISH	28
JOERGER	16
KNOFF	49
LAICEY	41
MAXWELL	37
MC CURDY	36
MC DONALD AND BUYS	32
MILLER	18
MURPHY	10
NIELSON AND DONNELLY PILLIKIN AREA 9	24
O'BRIEN	36
OGLE	54
PFEIFFER	7



Base map from part of Pl 2, California State Mineralogist's Rept XXXIV, 1938

MC DONALD AND BUYS	32
MILLER	18
MURPHY	10
NIELSON AND DONNELLY PILLIKIN AREA 9	24
O'BRIEN	36
OGLE	54
PFEIFFER	7
PILLIKIN AREAS 1-4	23
PILOT HILL	34
PLACER CHROME CO WORKINGS PILLIKIN AREA 5	26
SHELLY	39
SHEPPARD	42
SIMON	38
SIMPSON	19
SMITH	2
STAFFORD	48
STEELE	22
STIFLE	44
THOMAS AND MELDRUM	29
TRID CHROME CO PLACER GROUND	2
VEERKEMP	40
WALKER	17
WILEY	33
WILLIAMSON	31

Geology from U S Geological Survey Geologic Folios of the Placerville and Sacramento quadrangles

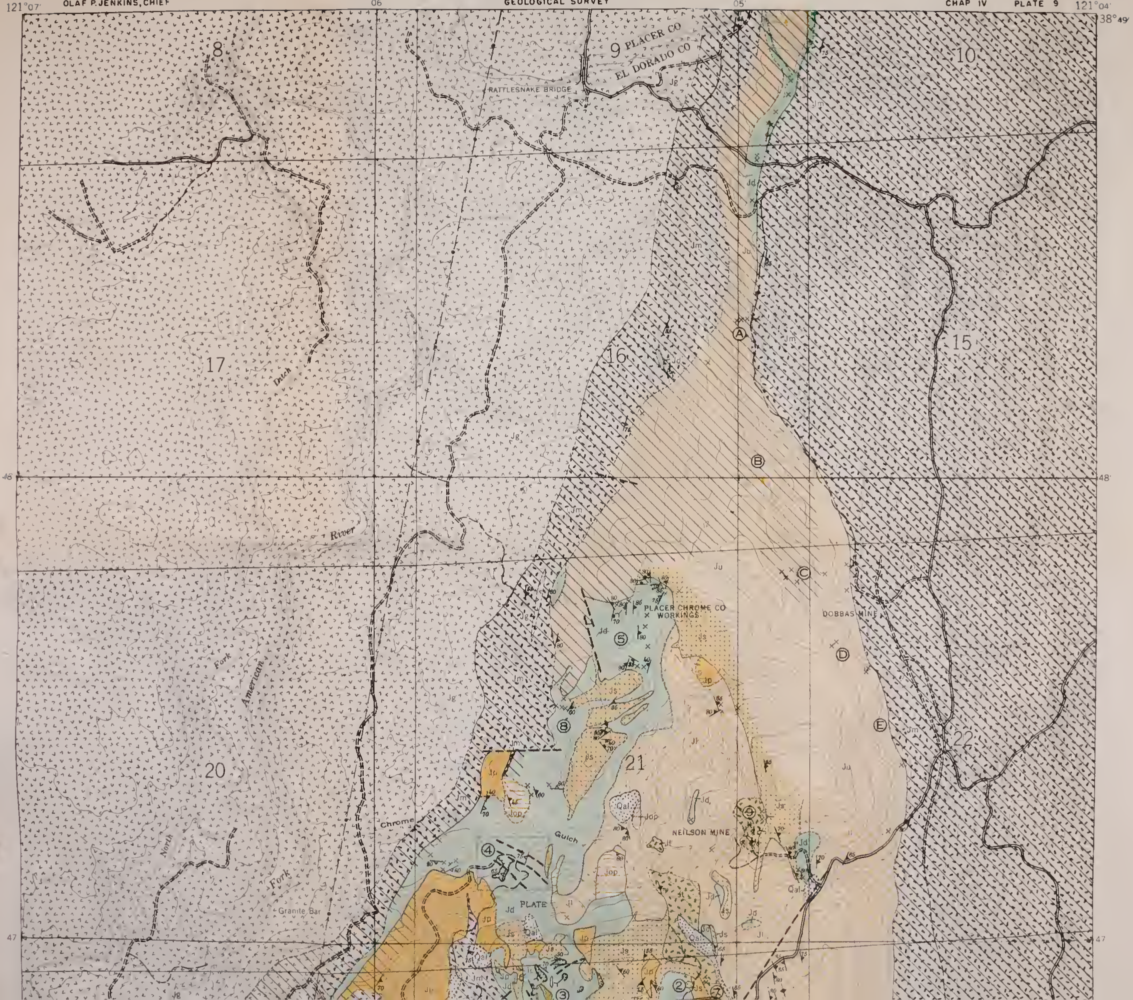
MAP OF WESTERN EL DORADO COUNTY, CALIFORNIA, SHOWING LOCATION OF CHROMITE DEPOSITS AND DISTRIBUTION OF SERPENTINE

1 0 1 2 3 4 5 Miles

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES
OLAF P. JENKINS, CHIEF

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BULLETIN 134 PART III
CHAP IV PLATE 9



EXPLANATION

QUARTERNARY

Qal
Alluvium and soil cover
(Shown only in area mapped in detail)

JURASSIC

Jg
Granodiorite
(Not mapped in detail)

Js
Silicified ultramafic rocks

Jt
Talcose ultramafic rocks

Jp
Pyroxenite

Jop
Banded olivine and pyroxene rocks

Jl
Lherzolite
(Largely altered to serpentine)

Jd
Dunite
(Largely altered to serpentine)

Ju
Undivided ultramafic rocks
(Lherzolite and/or dunite predominate in northern part of ultramafic mass, pyroxenite in southern part)

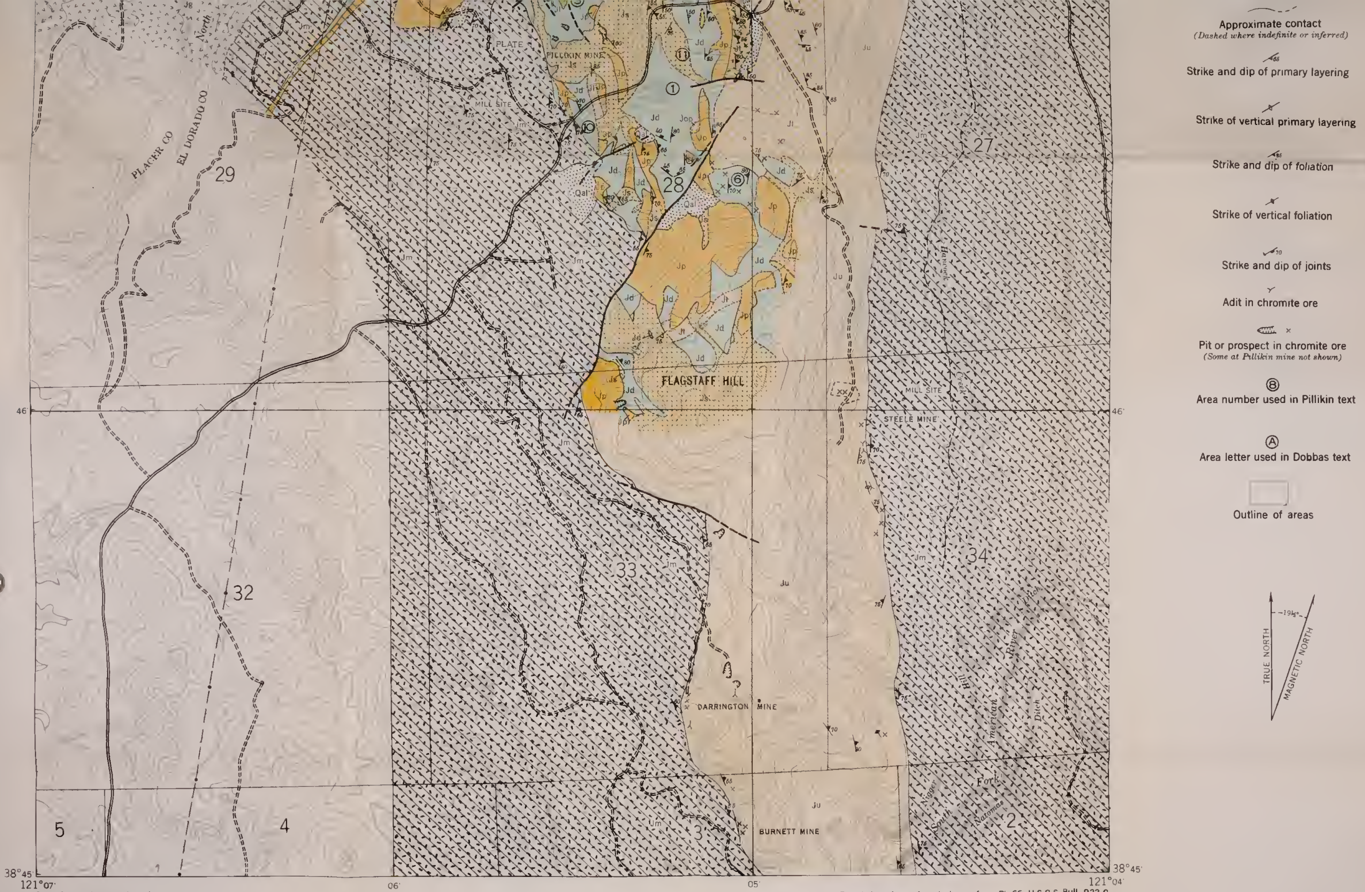
JURASSIC (?)

Jm
Undivided metamorphic rocks
(Mainly hornblende and chlorite schists derived from volcanic rocks; includes some limestone lenses and quartzite)

▨
Injection complex of granodiorite and metamorphic rocks

▨
Injection complex of ultramafic and metamorphic rocks
(Color pattern indicates injected rock)

Fault
(Dashed where approximately located)


Approximate contact
(Dashed where indefinite or inferred)
Strike and dip of primary layering
Strike of vertical primary layering
Strike and dip of foliation
Strike of vertical foliation
Strike and dip of joints
Adit in chromite ore
Pit or prospect in chromite ore
(Some at Pillikin mine not shown)
Area number used in Pillikin text
Area letter used in Dobbas text
Outline of areas
TRUE NORTH
MAGNETIC NORTH
19½°
PLACER CO
EL DORADO CO
North
PLATE
PILLIKIN MINE
MILL SITE
FLAGSTAFF HILL
STEELE MINE
DARRINGTON MINE
BURNETT MINE
Hancock Creek
South Fork American River
Natomas Ditch
Negro Hill
Jd
Jp
Js
Jt
Jm
Ju
Qal
27
28
29
32
33
34
5
4
3
2
46'
38°45'
121°07'
06'
05'
121°04'

Base from advance sheet by
U. S. Geological Survey, 1944
Subject to correction

Detailed geology of central area from Pl. 66, U.S.G.S. Bull. 922-O
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Geology of surrounding area by Garn A. Rynearson, 1949

Topographic and geologic drafting by K. M. Kozee

GEOLOGIC MAP SHOWING LOCATION OF CHROMITE MINES, FLAGSTAFF HILL AREA, EL DORADO COUNTY, CALIFORNIA

1000 500 0 1000 2000 3000 4000 Feet

Contour interval 20 feet
Datum is mean sea level

DIVISION OF MINES
OLAF P. JENKINS, Chief

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

UNITED STATES DEPARTMENT OF THE INTERIOR
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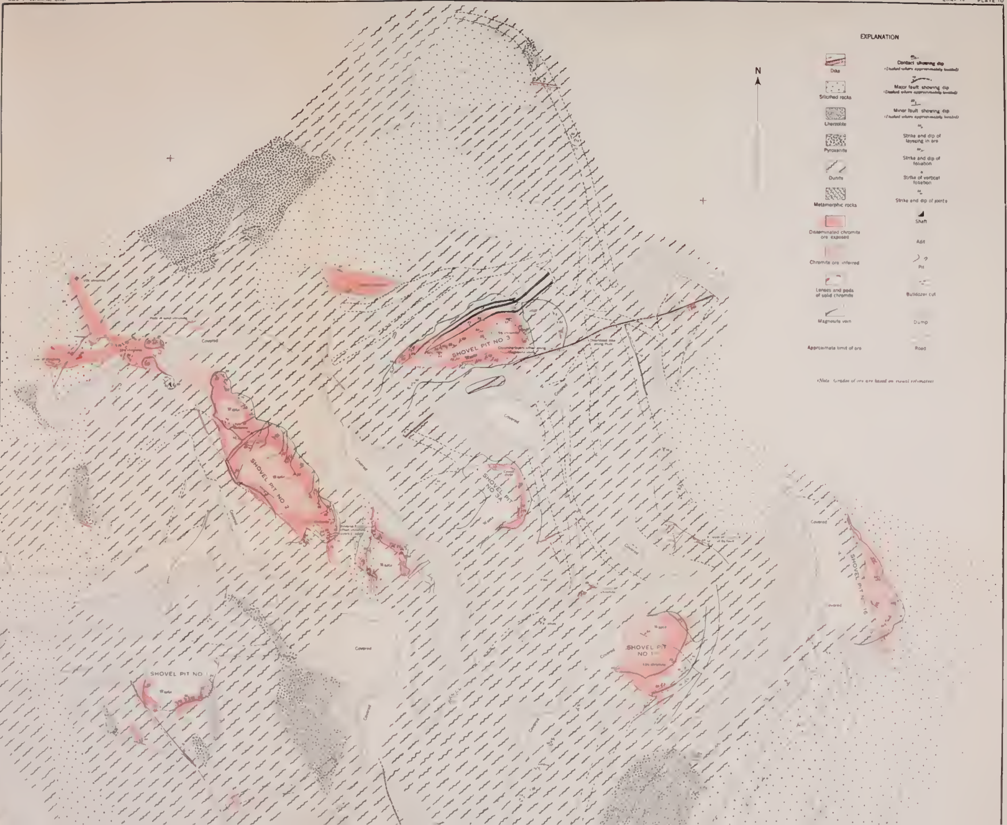

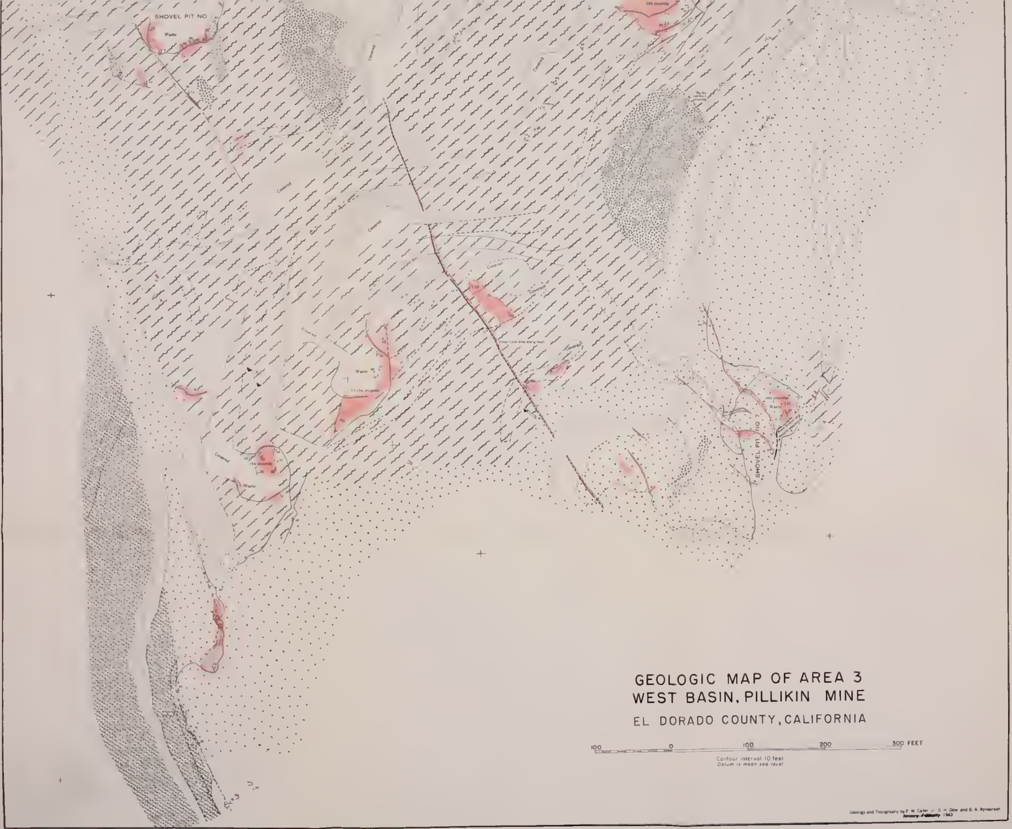

GEOLOGIC MAP OF AREA 3
WEST BASIN, PILLIKIN MINE

EL DORADO COUNTY, CALIFORNIA

100 0 100 200 300 FEET

Contour interval 10 feet
Datum is mean sea level

Geology and Topography by F. W. Cater Jr., D. H. Dow and B. A. Rynearson
January–February 1943

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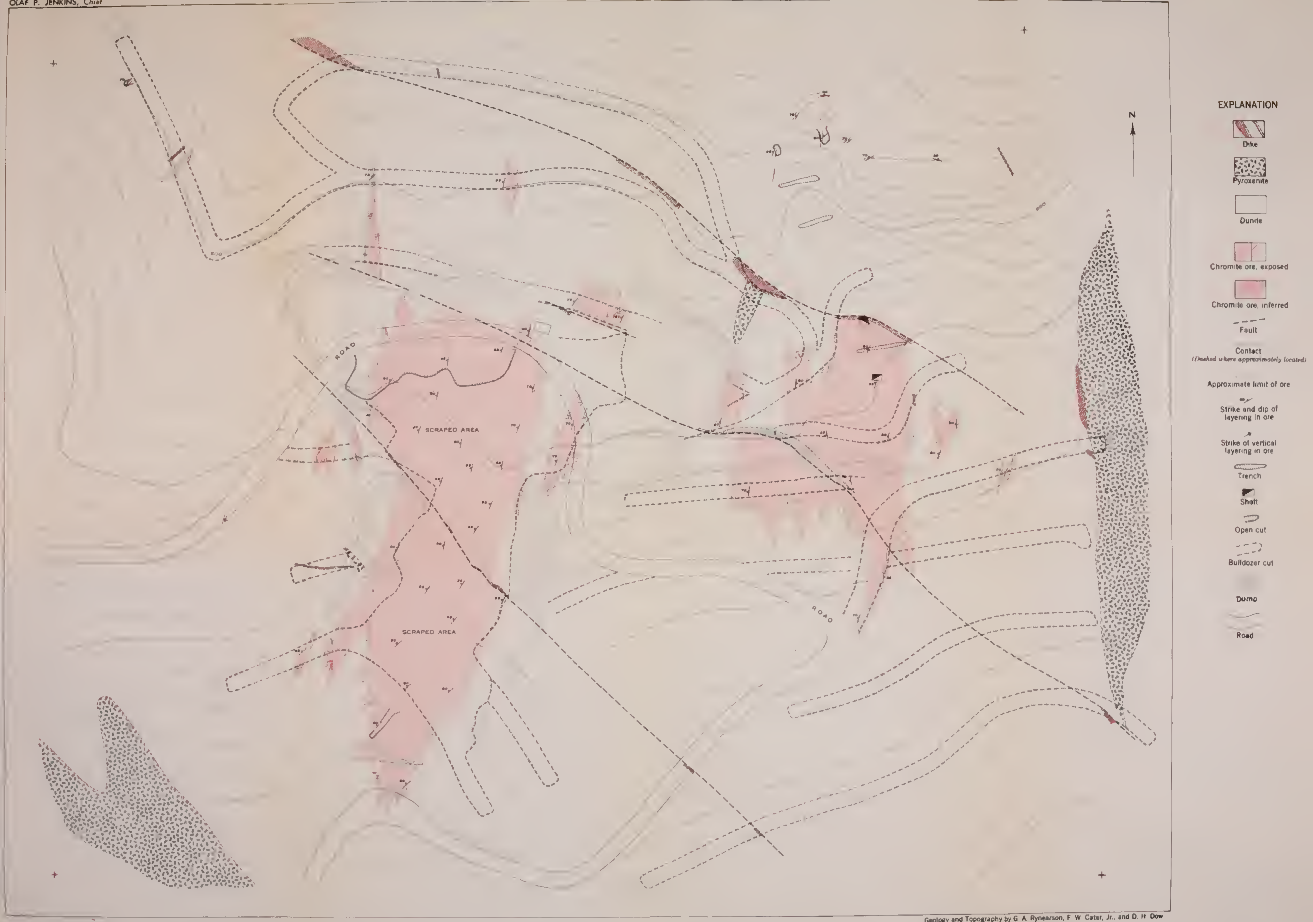
CHAP. IV PLATE II



Geology and Topography by G. A. Rynearson, F. W. Cater, Jr., and D. H. Dow
January, 1943

GEOLOGIC MAP OF NEW WORKINGS IN AREA 4. CHROME GULCH. PILLIKIN MINE. EL DORADO. CALIFORNIA

Contour interval 10 feet
(Datum is mean sea level)

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book

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EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO
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BULLETIN 134, PART III, CHAPTER 5 AUGUST 1953

ICAL INVESTIGATIONS
OF
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Bulletin 134
PART III—SIERRA NEVADA

CHAPTER 5
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RTHERN SIERRA NEVADA, CALIFORNIA
A, SIERRA, YUBA, BUTTE, AND PLUMAS COUNTIES)

By Garn A. Rynearson
l Survey, U. S. Department of the Interior

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